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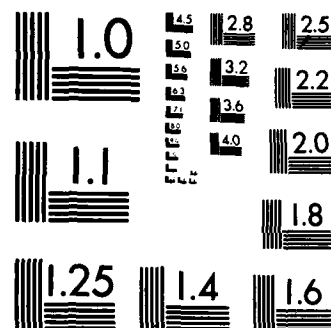
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A CREW EXPOSURE STUDY — PHASE I
VOLUME I — OFFSHORE

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16. Abstract The objective of this project was to characterize the exposure of offshore drilling and production workers to potentially hazardous aerosols (gases, vapors, mists and dusts) and liquids that may be encountered during their work activities. An evaluation of exposure to noise was also included in the project objectives. The major elements of the Phase I project were (1) a background study, (2) the development of an experimental plan, and (3) implementation of the experimental plan for exposure to aerosols and liquids on one offshore observation of seven days duration. The background study included (1) a search of the technical literature, and a review of current laws and regulations that apply to offshore facilities, (2) contacts with both domestic and international organizations with an interest in offshore operations, and (3) observation visits to fifteen offshore production and drilling facilities. The background observations identified aerosol contaminant emission sources and developed scenarios for the exposure of offshore workers to potentially hazardous aerosols and liquids. The background study was used to develop an experimental plan for characterizing the exposure of crew members to hazardous aerosols and liquids and to noise on offshore drilling and production facilities. A trial implementation of the experimental plan for aerosol and liquid exposure was carried out on four offshore facilities with drilling and production operations. Further implementation of the test, including noise measurements, on offshore facilities will be performed during Phase II of this project.					
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Dr. James Hammond of the University of Texas School of Public Health provided valuable assistance to the project team in the identification of dermal effects that may be associated with ingredients found in drilling fluid chemicals.

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EXECUTIVE SUMMARY

"A Crew Exposure Study - Phase I" is the title of a research project that has assessed the exposure of workers to potentially hazardous aerosols (gases, vapors, mists, and dusts) in both the marine bulk liquid transportation industry and the offshore oil and gas exploration/production industry. Because these industries differ with respect to their basic operations, chemical substances in the work environment, exposure potential and work schedules, the results have been published in two volumes.

- o Volume I - Offshore
- o Volume II - At-Sea

This volume addresses the Offshore portion of the study.

The main objective of this study was to characterize the exposure of offshore drilling and production workers to potentially hazardous aerosols and liquids that may be encountered in their work activities. A secondary objective to evaluate the exposure of these workers to noise was included in the project after its inception. The major elements of the Phase I effort to meet these objectives were (1) a background study, (2) the development of an experimental plan, and (3) implementation of the plan for aerosols on one offshore observation. Implementation of the test plan for noise exposure was deferred until Phase II.

Background Study

The objective of the background study was to generate an information and experience base that would define the potential hazard sources associated with operations that could place the offshore worker into contact with toxic and flammable substances.

The open literature was searched for reports on past and current research pertaining to flammable and toxic hazards of chemical vapors, current laws and regulations governing emissions and exposures, and vapor emission and dispersion as related to the offshore industry. This search provided information that was helpful to specific areas of the project, but contained little data from actual measurements of aerosol contaminant levels on offshore facilities.

Domestic and international organizations with an interest in offshore operations were also contacted for information. It was learned that the Norwegian Petroleum Directorate and the Royal Norwegian Council for Scientific and Industrial Research are also conducting studies of offshore health, safety and preparedness. However, there does not appear to be any duplication of effort between this Crew Exposure Project and projects of other organizations.

Background visits were made to a total of eight offshore production platforms and seven drilling rigs. These observations provided firsthand information concerning (1) the size of the crew, their work schedules and duties, (2) the types of equipment which may emit potentially hazardous aerosols, and (3) the types of operations during which crewmen may come into contact with potentially hazardous materials. Measurements of organic vapor concentration were made on two of the drilling rigs and four of the production platforms to aid in the identification of contaminant emission sources.

The background study identified three scenarios for the exposure of drilling rig crew members to potentially hazardous aerosols and liquids. these were:

- o inhalation of formation gases and vapors released from the drilling fluid at the shale shaker and mud pits during drilling,
- o inhalation of chemical dust particles from drilling fluid material during mud mixing operations, and
- o skin contact with the drilling fluid when adding or pulling pipe from the hole during drilling.

Observations and measurements on the production platforms identified several sources of gaseous and vapor contaminant emissions. There were:

- o fugitive emissions of gas and vapor from flanges, valves, threaded connections and poorly sealed gaskets,
- o emissions of gas and wet oil vapors from a flotation cell (part of the oil/water separation and water cleaning equipment) that was open for repair, and
- o accumulated gas in gas compressor rooms as a result of fugitive emissions from the compressor and fuel gas engine.

The accumulated information from this background study was used to formulate the experimental plan.

Experimental Plan

An experimental plan involving six separate activities was developed to identify, characterize and assess the effect of contaminant aerosol emissions and contact with potentially hazardous liquids. These activities were:

- o Identification of aerosol (dust, mist, vapor and gas) contaminant emission sources, and operations that involve skin contact with potentially hazardous liquids.

- o Characterization of the chemical composition and strength of the contaminant sources.
- o Area sampling for aerosols in work areas and living accommodation areas.
- o Observation and documentation of skin and clothing contact with drilling fluids and other liquids during work activities.
- o Documentation of work activities and personal sampling for exposure to aerosols for selected offshore workers.
- o Interpretation of the results of source, area and personal sampling data with respect to existing standards for industrial hygiene.

An experimental plan for measuring sound pressure levels and worker exposure to noise on the offshore drilling and production facilities was also developed. The experimental sampling plans were designed to be implemented during a seven-day observation of drilling rig and/or production platform operations on offshore facilities. An observation of seven days duration coincides with the schedule (seven days on, followed by seven days off) that is worked by most offshore crew members.

Two additional offshore visits to two drilling rigs and one production platform were made to provide more information about the composition of gas and vapor emissions from fugitive emission sources on production platforms and from drilling fluids on drilling rigs. These visits demonstrated the feasibility of performing a component analysis of contaminant gas and vapor samples with a portable gas chromatograph while offshore. The results of the component analysis indicated that the typical fugitive emissions found in the compressor rooms, well head areas, transfer pumps, gas turbines and engines consisted of a mixture of hydrocarbon gases and vapors. The concentration distribution of these emissions was typical of natural gas, with 85% to 95% methane, and decreasing amounts of ethane, propane, butane, pentane, and hexane.

Trial Implementation of the Experimental Plan

The experimental plan for aerosol and liquid exposure was given a trial implementation during a seven-day observation that included both drilling and production facilities on a total of four offshore facilities. All fugitive and major emission sources of dusts, vapors and gases were identified and characterized. Personal exposure to respirable dust was measured for both a roughneck and an observer during mud mixing operations. Levels of hydrocarbon gas and vapor concentration were determined near the shale shaker on the drilling rig, and in a fuel gas compressor room, and downwind of an oil flotation cell (used to clean produced water before it is discharged into the sea) on the production platforms. The activities of the drilling floor crew were observed to provide documentation of dermal exposure to the drilling fluid.

The primary conclusions of the trial test plan implementation are the following:

- o Most contaminant gas and vapor emissions from production platform facilities are fugitive emissions. These typically have high gas concentration, but a low emission flowrate. The gas and vapor composition of these emissions was typical of natural gas.
- o Fugitive gas and vapor emissions into well ventilated areas typically do not constitute a health hazard, although they may present a flammability hazard. However, fugitive emissions into poorly ventilated rooms and enclosed spaces may cause the gas concentration to increase with time.
- o Existing USGS regulations require that gas sensors shall be used in all inadequately ventilated, enclosed, high hazard areas.
- o Samples of contaminant gases collected in a compressor room with adequate ventilation, and downwind of an oil/water flotation cell (that was emitting natural gas and wet oil vapors) gave concentration values that were below the maximum permissible levels for toxicity, flammability, and asphyxiation by current standards.
- o Adding dry drilling fluid chemicals into the hoppers in the mud mixing area may produce a localized cloud of fine dust particles in the air. Materials that are finely ground will emit more dust than coarse ground or bead material. The mud mixing area should be well ventilated to avoid the accumulation of dust in the air.
- o Measurements of the respirable dust concentration in the breathing zone for a roughneck and an observer during mud mixing, indicated that the concentration levels of dust were below the maximum permissible levels for nuisance particulate matter by current standards. This result may not be typical of all drilling rigs.
- o Under normal drilling conditions, gas from underground formations is prevented from entering the drilling fluid by the hydrostatic head of the drilling fluid column. However, when gas cutting of the drilling mud does occur, formation gas will be released at the shale shaker until the mud weight and formation pressure are balanced. Good ventilation of the shale shaker room (if enclosed) is important to prevent the accumulation of gas.
- o Measurement of contaminant gas in shale shaker areas during drilling with water base mud indicated that the concentration level was below the maximum permissible level by current standards. These areas were well ventilated

to prevent gas accumulation. This result may not apply to rigs with shale shakers located in poorly ventilated rooms.

- o Measurements of contaminant gas in shale shaker and mud pit areas during drilling with an oil base mud indicated that the concentration level was acceptable by current standards. The contaminant gas consisted of vapor from the diesel fuel base for which a TLV-TWA value of maximum permissible concentration has not been defined.
- o Dermal contact with some commonly used drilling fluid materials is known to cause skin burns (from caustic soda) and irritation of existing skin wounds (calcium chloride, calcium bromide). However, other drilling fluid materials may contain ingredients (sometimes as impurities) that can produce skin sensitization and irritation from dermal contact. A preliminary list of these ingredients and their dermal exposure effect has been prepared. Additional effort is required to complete this list and to cross-reference it to a list of drilling fluid materials.
- o Extensive contact of water base drilling fluids with the clothing and skin of the drilling floor crew members was not observed. The use of good operating procedures when adding new lengths of drill pipe to the drill string can minimize the potential for skin contact with the drilling fluid. These include (1) having a check valve in the drill collar to prevent the flow of mud back through the drill pipe, (2) allowing the mud pumps to stop completely before breaking the connection between drill pipe and kelly, (3) washing the drill pipe and rotary table with drill water before breaking the connection, (4) maintaining good housekeeping standards and keeping the drains open, and (5) wearing long-sleeve shirts and gloves. Operating procedures and drill floor standards for housekeeping will vary from one rig to the next.

The observation of drilling with an oil base mud indicated that the potential for skin contact could be greater than for water base mud. This is because the oil base mud is not water soluble and could not be washed from the drill pipe and rotary table before the drill pipe to kelly connection was broken. The drilling floor became slippery and accidental contact with the drilling fluid could not be avoided.

- o Any crewmember who has a skin wound or broken place on exposed hands and arms should wear impervious gloves and forearm coverings. Many substances like drilling mud, chemicals and fuel will severely irritate the abraded skin and subtiissue.

These results of the trial test plan implementation are specific to the actual platforms that were visited. Other platforms will differ in design, equipment, operation procedures, and in the provision and use of personal protective equipment (such as dust masks). Drilling fluid composition (water base or oil base mud), and the drilling fluid program are likely to be site specific. Drilling floor procedures and rig "housekeeping" may also vary greatly from one rig to the next. On the other hand, the types of hydrocarbon gas and vapor emissions encountered on the production platforms may not be significantly different from one site to the next. The trial execution of the experimental plan is the culmination of "A Crew Exposure Study - Phase I." The refined test plan will then be further implemented in a dedicated data collection effort, "A Crew Exposure Study - Phase II," aboard additional offshore drilling rigs and production platforms. The additional observations and measurements performed during Phase II will help to substantiate conclusions that are generally true of the offshore industry, and identify those which are subject to variability due to equipment or operational procedures.

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GLOSSARY OF TERMS

ACGIH	- American Conference of Governmental Industrial Hygienists
AIHA	- American Industrial Hygiene Association
CHRIS	- Chemical Hazards Response Information System
LEL	- Lower Explosive Limit
NIOSH	- National Institute for Occupational Safety and Health
OSHA	- Occupational Safety and Health Administration
OVA	- Organic Vapor Analyzer
PEL	- Permissible Exposure Limit
SwRI	- Southwest Research Institute
TLV-STEL	- Threshold Limit Value - Short Term Exposure Limit
TLV-TWA	- Threshold Limit Value - Time Weighted Average
UEL	- Upper Explosive Limit
USCG	- United States Coast Guard
TLV-STIL	- Threshold Limit Value - Short Term Inhalation Limit

I. INTRODUCTION

This final report presents the results of a Crew Exposure Study performed by Southwest Research Institute for the U. S. Coast Guard, Office of Research and Development, Marine Safety Technology Division. The purpose of this study is to characterize the on-the-job exposure of crew personnel to hazardous materials during routine and unusual work activities on offshore drilling and production facilities and on liquid bulk chemical tankers and barges at sea. Because the nature of the potential hazards and the work routines of offshore workers differ greatly from those for tanker and barge crew personnel, the results of the Crew Exposure Study are published in two separate volumes. Volume I reports the results for offshore oil and gas drilling and production operations. Volume II reports the results for liquid bulk tanker operations at sea.

I.1 Background

Higher real crude oil prices and a concern for the security of imported oil and gas supplies has resulted in a rapid acceleration of domestic offshore oil and gas exploration. The October 1981 Facts and Forecasts issue of Ocean Industry estimated that 1375 offshore U. S. wells would be drilled in 1981 compared with 1241 in 1979 and only 830 in 1974. This increase in drilling activity is expected to result in similar increases in offshore oil and gas production, attendant servicing from manned support vessels, and domestic petrochemical transport in ships and barges.

The United States Coast Guard is responsible for the health and safety of offshore and marine transportation workers through the Ports and Waterways Safety Act as amended in 1978. The Coast Guard is aware that there are potential health and safety hazards from the flammable and possibly toxic nature of some of the substances and materials involved in offshore drilling and production operations. However, there has been very little information reported to date to document the workplace concentrations and actual exposures of offshore workers to potentially hazardous substances during their work activities. This type of information is desirable in order to determine whether additional regulation is needed to provide for the health and safety of offshore workers. Therefore, the Coast Guard initially contracted with Southwest Research Institute to perform a research project that would characterize the exposure of offshore drilling and production workers to potentially hazardous liquids, gases, dusts and vapors. During the conduct of the project, the scope was expanded to include an evaluation of noise exposure.

I.2 Objectives

The main objective of this study was to characterize the exposure of offshore drilling and production workers to potentially hazardous vapors, gases, dusts and liquids that may be encountered in their work activities. To accomplish this objective, four separate tasks were identified, each with a specific objective. A secondary objective to evaluate noise exposure was included in Task 5.

Task 1 - Conduct a background study to define the potential hazard sources associated with operations that may bring the offshore worker into contact with toxic and flammable substances.

Task 2 - Develop analytical models, if appropriate, to simulate the effect of contaminant sources on exposure to hazardous substances during the operations observed in Task 1. This task will help to guide the design of an experimental contaminant sampling plan for measuring worker exposures.

Task 3 - Develop the experimental measurement techniques and an experimental test plan for acquiring the data needed for an assessment of worker exposure.

Task 4 - Conduct an observation on an offshore drilling and/or production facility in order to evaluate the experimental test plan and to provide an initial assessment of worker exposure.

Task 5 - Develop an experimental plan for determining sound pressure levels and worker exposure on offshore drilling rigs and production platforms.

I.3 Project Work Tasks

Each task has a set of specific activities that were performed during this study. The activities for each task are outlined below.

o Task 1 - Background Study

- Review the reports of previous investigations related to this project that are identified by literature searches and written inquiries.
- Review the set of existing regulations pertaining to worker exposure in offshore environments.
- Compile a set of chemical, physical and toxicological property data for potentially hazardous substances encountered in offshore operations.
- Perform on-site observations on offshore drilling and production facilities to identify contaminant sources and to document worker activities that may involve exposure to potentially hazardous materials.

o Task 2 - Analytical Modeling

- Determine whether the contaminant sources observed in Task 1 are amenable to analytical modeling.

- Adapt existing models to simulate the emission and dispersion of airborne contaminants.
- Evaluate the analytical model results for contaminant concentration distribution from typical contaminant sources.
- o Task 3 - Experimental Test Plan
 - Develop on-site sampling and analytical methods for determining workplace concentrations and personal exposures for dusts, mists, gases and vapors.
 - Design a test plan for implementing the contaminant sampling and analysis methods on drilling rigs and production platforms during a 7-day offshore observation.
- o Task 4 - Offshore Observation to Implement the Test Plan
 - Document the activities of workers with the greatest potential for exposure to hazardous contaminants.
 - Perform the program of personal and workplace contaminant sampling as required by the test plan.
 - Analyze and interpret the results of the sampling program with respect to established criteria for exposure to flammable and/or toxic substances.
- o Task 5 - Offshore Noise Exposure
 - Conduct a literature survey to locate existing guidelines and experimental data for offshore structures.
 - Determine procedures for setting guidelines.
 - Develop an experimental plan for measuring sound pressure levels and worker exposure.

The results for Task I through IV are presented in Chapters II - V, while the noise study (Task V) results are contained in Chapter VI.

I.4 Perspective

The trial execution of the experimental plan represents the culmination of "A Crew Exposure Study - Phase I." The refined test plan will then be further implemented in a dedicated data collection effort, "A Crew Exposure Study - Phase II," aboard additional offshore drilling rigs and production platforms.

II. BACKGROUND STUDY

II.1 Literature Search

The initial effort on this project was to conduct a computerized and manual search of the open literature. The purpose of the search was to uncover either abstracts or bibliographic citations that relate directly or indirectly to ongoing or past research. Specific areas of interest included flammable and toxic hazards of chemical vapors, current laws and regulations governing vapor emissions and exposures, vapor emissions, and plume dispersion as related to the offshore industry. Key words or phrases were first defined and then arranged into the group files shown in Table II.1. These files were combined on a computer and applied sequentially to various data banks. The productivity of the composite searches, including offshore and marine industries, is summarized in Table II.2.

In addition to the computer search, a manual search was made of the Offshore Technology Conference proceedings for the period covering 1965-1980.

A categorized bibliography of the literature items that have been ordered, received, and reviewed is presented in Appendix A. Much of this literature was helpful to specific areas of this project; however, none of the papers encompassed the complete subject matter of this project.

II.2 Related Occupational Health Investigations

A search was conducted to identify domestic and international governmental agencies, research laboratories, and industry associations that have a continuing concern for safety and health on offshore drilling and production facilities. Eight organizations were contacted by letter requesting information on past or current research efforts to characterize the occupational exposures of offshore workers to all forms of workplace contaminants, i.e., liquids, vapors, gases, dusts, and mists. The contacted organizations are:

- o Marine Technology Directorate
Science Research Council
London, England
- o Marine Technology Center
Trondheim, Norway
- o Norwegian Petroleum Directorate
Stavanger, Norway
- o National Petroleum Council
Washington, D.C.
- o Det norske Veritas
Oslo, Norway

TABLE II.1. COMPUTER SEARCH STRATEGY

<u>GROUP I</u>	<u>GROUP II</u>
Gas ? *	Toxic ?
Vapor ?	Hazard ?
Mist ?	Flam ?
Dust ?	
Aerosol ?	<u>GROUP IV</u>
Particulat ?	Hygiene
	Health
<u>GROUP III</u>	Occupational (w) Safety
Drill ?	Occupational (w) Disease
Transport ?	Industrial (w) Safety
Deliver ?	Industrial (w) Disease
Distribut ?	
Convey ?	<u>GROUP V</u>
Transfer ?	Model ?
Rout ?	Micromeritic ?
Stor ?	Disper ?

* ? - denotes a root word code or truncator. All words in the title or abstract that contain the truncator will respond.

TABLE II.2. PRODUCTIVITY OF COMPOSITE SEARCH

File Name	No. of Citations	No. of Finds
APILIT	405	35
LABORDOC	126	2
COMPENDEX	125	22
APTIC	173	4
NTIS	65	9
ENVIROLINE	34	8
POLLUTION ABSTRACTS	18	5
MRIS	14	10
ENVIRONMENTAL REPORTS BIBLIOGRAPHY	254	30
CONFERENCE PAPERS INDEX	613	18
OCEANIC ABSTRACTS	261	26
SSIE (CURRENT RESEARCH)	151	8
TOTALS	2239	177

- o International Association of Drilling Contractors
Houston, Texas
- o Society of Petroleum Engineers
Dallas, Texas
- o American Petroleum Institute
Washington, D.C.

Replies were received from seven of these organizations. Six of the seven replies indicated that there were no past or ongoing research activities pertaining specifically to worker health on offshore facilities. Only the Norwegian Petroleum Directorate appears to have an offshore health research program. Three potentially relevant projects were identified in their publication entitled "NPD Research Into Preventive Safety Measures and Contingency Planning."

- o Human Health and Safety - Criteria for Analysis
- o Medical Information System
- o Safety and Work Environment on Fixed Installations.

The first two projects were in the evaluation or pre-initiation phase. The third project is sponsored jointly by NPD and the Norwegian Ship Research Institute. The project reports were obtained but, unfortunately, were in Norwegian. However, correspondences with NPD have indicated that this project is not a duplication of their efforts.

An unsolicited response was received from the NTNF (Royal Norwegian Council for Scientific and Industrial Research). NTNF and NPD jointly administer the Norwegian government's research program on offshore safety and preparedness. A potentially relevant NTNF publication entitled "Safety and the Quality Working Life in Offshore Production" has been requested but was not received.

There does not appear to be any duplication of effort between the Crew Exposure project and projects of other national and international organizations.

II.3 Pertinent Regulations

This section contains a review of the current and proposed regulations relative to the offshore portion of this project. These regulations are briefly discussed below and are summarized in Appendix H.

U. S. Coast Guard Regulations

The applicable title in the CFR which addresses the Coast Guard's authority over the subject matter is Title 33. Subchapter N of this title discusses general provisions, inspections, operating requirements, and safety zones for offshore structures.

On February 11, 1980, the USCG and OSHA jointly published a Memorandum of Understanding (MOU) concerning occupational safety and health for offshore facilities on the Outer Continental Shelf (Federal Register, Vol. 45, No. 29, page 9142). This MOU defines agency responsibilities, procedures for development and enforcement of standards, training, and implementation. In essence, under this MOU, the USCG has responsibility for the development and application of health and safety standards on the OCS. OSHA will continue to apply general standards to conditions not covered by the Coast Guard jurisdiction.

U. S. Geological Survey Regulations

The applicable title in the CFR, which addresses the USGS's authority over offshore drilling and production, is Title 30. Parts 221, 250, and 251 of this title are of particular interest since they discuss air quality and workmanlike operations.

The USGS has also published a set of Outer Continental Shelf orders for the Gulf of Mexico. Orders Five (5) and Seven (7) are pertinent to this study. These orders discuss items such as electrical code requirements, fire and gas detection systems, liquid disposal, solid material disposal, and pollution inspections.

Although many of these regulations discuss operational procedures, none seem to deal with personal protection of the workers in their various workplaces. These personal protection requirements, such as protective clothing or eyewear, are instead governed by company policies and vary from platform to platform.

II.4 Chemical, Physical, and Toxicological Properties Data

During the early stages of this project, an attempt was made to determine the various components of drilling fluids which were likely to be encountered on observation trips. Appendix E, entitled "Drilling Fluids and Drilling Fluid Additives" presents an outline categorized by primary application of the above information. This information was obtained from the references listed in Appendix E.

Further research during the course of the project yielded a categorized list of the most commonly used drilling fluid additives in the Gulf of Mexico. This list is included as Appendix F, entitled "Competitive Mud Products." This list cross-references a general item and its primary application with the various tradenames of the largest suppliers. Those entries marked with an asterisk are substances that have been observed by SWRI personnel during offshore platform visits.

Chemical, physical, and toxicological properties for the underlined drilling fluid additives of Appendix F are presented in Appendix G. The information included in this appendix has come from Material Safety Data Sheets supplied by the producers of the substances. Many other categories were initially incorporated into Appendix G, but had to be removed because the information was not available due to the nature of the substance. The LEL, UEL, STEL, STIL, and Odor Threshold were not available for inorganic

compounds or organic compounds with proprietary blends. For organic compounds, this information is readily obtainable from CHRIS, Volume II (Reference 10). Other categories removed from the initial list include surface tension, viscosity, vapor pressure, critical temperature, critical pressure, particle size range, minimum ignition energy, minimum ignitable concentration, and warning labels.

The above three appendices were used as input for determining the dermatological and ocular classification of drilling fluids and their identified chemical substances, along with other materials in the mentioned appendices. As a result, Tables I and II of Appendix I were constructed. Also included in this appendix is the list of references utilized during this effort.

All chemical substances in the products that could be identified as hazardous were classified by both their dermatological effects and potential eye hazards. Table I of Appendix I is a tabulation of the chemicals which have either skin or eye effects. The headings in this table to classify the various chemical substances are:

Primary Irritant
Corrosive or Ulcer Hazard
Allergic Sensitizer
Photosensitizer
Acne-like Diseases
Carcinogenic
Systemic by Skin Absorption
Eye Hazard

These headings are further explained in the Glossary of Table Headings in Appendix I.

Table II of Appendix I is a tabulation of inert chemicals, natural materials, and other substances that were found to have no known skin or eye hazard in drilling fluid products usage.

No attempt was made to classify commercial products because the details of the compositions are often both a trade secret and frequently changed. We, therefore, suggest that the user of these products obtain current Material Safety Data Sheets for each product.

Appendix J, entitled "Chemical Property Data - Gases and Hydrocarbon Vapors" contains a table of toxicological and flammability properties of many of the gases and vapors that may be detected on offshore facilities.

III. PRELIMINARY PLATFORM OBSERVATIONS

Many types of drilling rigs and production platforms are currently in use in the U. S. coastal waters. Table III.1 presents the functions, water depths, drilling depths, advantages, and disadvantages of these platform types. Inherent in the design of each of these platform types are various deck arrangements and degrees of equipment enclosure. Appendix B, entitled "Classification of Offshore Drilling Rigs and Production Platforms," discusses the basic design and usefulness of the various types of drilling rigs found in U. S. coastal waters.

III.1 Observation Objectives and Activities

The objectives of the preliminary platform observations were to become familiar with offshore activities and operations, gather information on the activities and number of workers, and identify the possible contaminant sources that exist on both drilling rigs and production platforms. The final objective was then to identify workers who had a high probability of potential exposure.

To meet these objectives, it was necessary to define the rig or platform types to be included in the observations. Important to the choice of observation sites is the fact that layout of equipment and its degree of enclosure are very instrumental in determining the potential for hazardous conditions to exist in the form of dusts or vapors. Equipment of significant interest are those that produce source contaminants, are in close proximity to continuous work activities, and are shielded from ventilating winds.

III.2 Drilling Rigs

III.2.1 Definition of Visited Facilities

In order to complete the objectives outlined above for drilling rigs, qualitative surveys were performed on various types of drilling rigs. Table III.2 summarizes the platforms on which observations were made. In the composite, nine platforms were surveyed, including a jack-up, drill barge, 4-pile package with a tender barge, a semi-submersible, three 4-pile packages, and two 8-pile packages.

The essential equipment systems observed on these platforms related to drilling are the power generating system, drill floor machines, drilling fluid system, and cementing unit. The purpose and potential hazardous sources of the major pieces of equipment in each of these systems are summarized in Appendix C. Those areas which were identified as potentially hazardous will be discussed further in Section III.2.3.

III.2.2 Worker Activities

There are many types of workers necessary to the operation of an offshore platform with drilling facilities. Table III.3 presents the categories and typical number of workers on these platforms.

TABLE III.1. OFFSHORE PLATFORM TYPES

Platform	Function	Average Water Depth (ft)	Maximum Drilling Depth (ft)	Advantages	Disadvantages	Remarks
Drill Ship/Drill Barge	Drilling	10 - 3,000	25,000	1. Can be used in wide range of water depths 2. Little setup time is required.	1. Not very stable in deeper water. 2. Mooring system is difficult in rough sea for drill ship.	Lower decks enclosed
Jack-up	Drilling	70 - 350	30,000	1. Low operating expense 2. Stable, no motion compensator required	1. Jacking is a delicate process 2. Water depth must be less than 350' 3. Hull balance can be a problem during towing	Lower decks often enclosed
Semi-submersible	Drilling	600 - 4,500	30,000	1. Can be used in deep water up to 6,000' 2. Good motion characteristics	1. High cost	
Submersible	Drilling	20 - 100	30,000	1. Stability	1. High cost 2. Difficult to move	
Jacket-Type	Drilling/Production	up to 1,000	~30,000	1. Stability		
Gravity Platforms (Steel & concrete)	Drilling/Production	200 - 500	~30,000			Equivalent to submersible
Tension Leg Platforms (TLP)	Drilling/Production	4,000	~30,000			Similar to semi-submersible
Articulated Column	Production	up to 1,000	-			
Guyed Tower	Production	600 - 2,000	-			

TABLE III.2. PRELIMINARY OFFSHORE OBSERVATIONS OF DRILLING RIGS

Company	Platform Class	Operation
B	Jack-up	Drilling-Oil
	4-Pile Package	Drilling-Oil
C	4-Pile Package with mud Tender	Drilling-Oil
	Semi-submersible	Exploratory Drilling
D	4-Pile Package	Drilling-Oil/Gas
	8-Pile Package	Drilling-Oil/Gas
E	8-Pile Package	Drilling (2 rigs on one platform)
F	Drill Barge	Drilling-Oil
G	8-Pile Package	Drilling

TABLE III.3. WORKERS ON PLATFORMS
WITH DRILLING FACILITIES

Category	Typical Number
Driller	1
Floorman	2
Derrickman	1
Floorman in Charge of Shale Shaker	1
Tool Pusher	1
Motorman	1
Galley Crew	2
Companyman	1
Geologist	1
Mud Engineer	1
Cementing Crew	3
Mud logging	3
Well logging	2
Welder	1
Roustabout Crew	3
Janitor	1
Mechanic	1
Electrician	1

Table III.4 outlines the workers' typical work activities and their potential exposures to hazardous sources during a working day.

The majority of the workers work a 7-day-on, 7-day-off, 12-hour day schedule. Workers such as the cementing crew and well logging crew are only on the platform when their services are needed, which may be only a few days. Other workers such as mechanics, electricians, and geologists are available to service a number of platforms in a given area.

III.2.3 Identification of Contaminant Sources

From the preliminary observations on drilling rigs, it was possible to identify three potential exposure situations: (1) skin contact of drilling fluid, (2) inhalation of dusts, and (3) inhalation of hydrocarbon vapors.

The first type of worker exposure that was observed was skin contact with the drilling fluid. The clothing requirements on a given platform were dictated by the drilling company. Some companies required long-sleeve full coveralls with gloves, hardhat, and safety glasses, but others had no formal requirements and left the dress up to the individual workers.

Figure III.1 illustrates two floormen, with short-sleeve coveralls and no safety glasses, whose skin and clothes had become covered with drilling fluid during the pulling of drill string. The clothing was not made of an impervious material. Although not all of the drill floor workers that were observed had this level of skin contact with the fluid, many had fluid on their hands and arms. Another activity involving skin contact with drilling fluid was observed during testing of the mud properties by the derrickman or mud engineer. The floorman in charge of the shale shaker also had splatters of the fluid on his skin and clothes.

The second type of worker exposure that was observed was inhalation of dusts when dry chemicals were being added to the drilling fluid. Many of the mix hoppers on the platforms were in the corner of an enclosed room with little natural ventilation. The effectiveness of the installed ventilation systems was questionable because of their locations relative to the dusty area, i.e., the area where the bags were broken and chemicals added to the mix hopper was remote to any general ventilation system.

The third type of worker exposure that was encountered was inhalation of hydrocarbon vapors or gases. This type of exposure appears to be more prevalent on production platforms than on drilling rigs. However, exposure to hydrocarbons in the drilling fluid returning from the well hole is possible. The workers with the greatest exposure potential are the floormen, especially the floorman in charge of the shale shaker. Platform workers told SwRI personnel that the person tending the shale shaker would be the first to experience any vapors from the drilling fluid and would be the one that would be exposed to the highest

TABLE III.4. WORKER ACTIVITIES ON PLATFORMS WITH DRILLING FACILITIES

Worker	Typical Work Activities	Potential Exposure to Contaminant Sources
Driller	Operates controls for the drawworks.	Skin contact of drilling fluid. Vapors in drilling fluid and hydrocarbon gases.
Floormen	Assist driller by handling drill string. Always on the drill floor or loading pipe onto the drill floor.	Skin contact of drilling fluid. Vapors in drilling fluid and hydrocarbon gases.
Derrickman	Assists on drill floor during a trip. His position is at the top of the derrick handling the drill string. He is also assigned to the mud room where he checks the properties of the drilling fluid.	Vapors from drilling fluid in the mud pits. Dust occurring as a result of addition of dry chemicals. Skin contact with both wet and dry chemicals.
Floorman in Charge of Shale Shaker	Assists on drill floor when needed. His normal position is at the shale shaker where he supervises its operation.	Skin contact of drilling fluid while on drill floor. Vapors in drilling fluid being released in the shale shaker area. Skin contact from fluid spray at the shaker table.
Tool pusher	Supervises and coordinates all activities and contract workers on the platform.	Various dusts, vapors, and skin contact while supervising the activities.
Motorman	Checks operation of engines, generators, compressors, pumps, and other accessories. He checks lubrication oil and makes minor adjustments on the engines but no major repairs.	Vapors from machinery in various rooms in which he works. Oil mists from the machinery.

(Continued)

TABLE III.4. WORKER ACTIVITIES ON PLATFORMS WITH DRILLING FACILITIES (Cont'd)

Worker	Typical Work Activities	Potential Exposure to Contaminant Sources
Galley Crew	Prepare meals and clean kitchen area. Stays indoors a majority of the time.	Vapors that may enter the living quarters through the air conditioning system.
Companyman	Oversees all work activities and communicates with the oil company for whom he works.	Various dusts, vapors, and skin contact while supervising operations.
Geologist	Analyzes cuttings from the well for rock type.	Skin contact with the drilling fluid on the cuttings.
Mud Engineer	Oversees the drilling fluid system and specifies the type and amount of chemicals to be added when specific properties are necessary.	Vapors from drilling fluid in the mud pits. Dust occurring as a result of addition of dry chemicals. Skin contact with both wet and dry chemicals.
Cementing Crew	Cementing of casing during various phases of drilling.	Dust as a result of mixing. Skin contact with the cementing material.
Mud Logging Crew	Sampling and testing of drilling fluid returning from the hole. Properties of the fluid and gas levels are recorded.	Skin contact with drilling fluid while obtaining sample.
Welder	Repairs and fabricates metal structures on the platform.	Vapors and mists that may be in the air. Welding fumes.
Roustabout Crew	Handle routine maintenance necessary on the platform.	Vapors and mists that may be in the air.

(Continued)

TABLE III.4. WORKER ACTIVITIES ON PLATFORMS WITH DRILLING FACILITIES (Concl'd)

Worker	Typical Work Activities	Potential Exposure to Contaminant Sources
Well logging Crew	Analyze core samples obtained from the well hole.	Vapors that may be in the air.
Janitor	Maintains cleanliness in the living quarters. Stays indoors a majority of the time.	Vapors that may be taken up in the air conditioning system.
Mechanic	Repairs the engines, compressors, generators, and pumps on the platform.	Vapors from machinery in various rooms in which he works. Oil mists from the machinery.
Electrician	Repairs faulty wiring of the equipment on the platform.	Vapors that may be in the air.

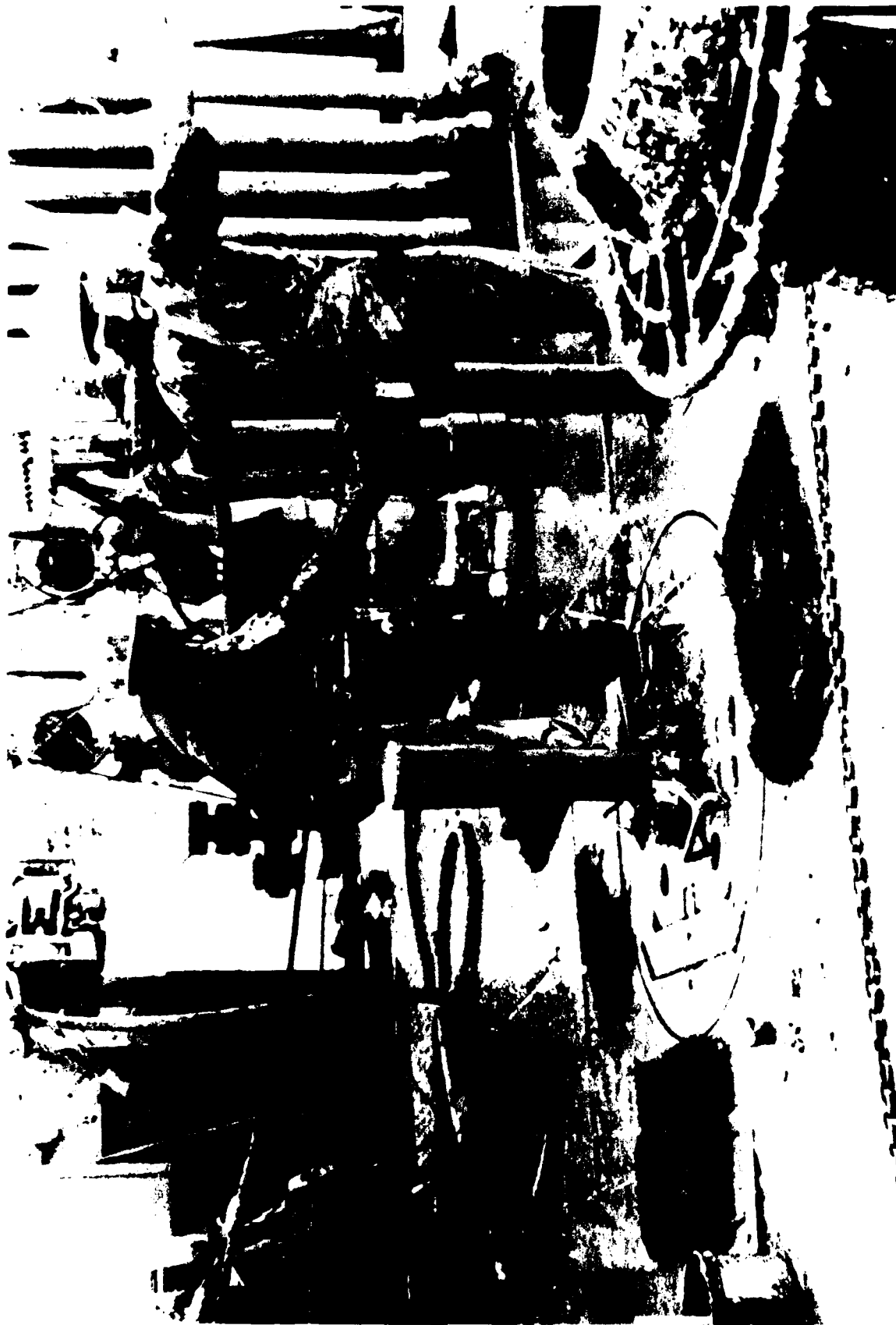


FIGURE III.1.1. EXAMPLE OF DERMAL EXPOSURE TO DRILLING FLUIDS

concentrations of vapor or gases. It should be noted that the most common gases (methane, ethane, and propane) are classed as simple asphyxiants as opposed to toxicants.

To summarize, the routine exposure potential for workers on a platform with drilling facilities includes skin contact with the chemicals in the drilling fluid and inhalation of dusts when dry chemicals are added to the drilling fluid. During non-routine activities, potential exposures include inhalation of various vapors and gases released from the drilling fluid, the oil or natural gas, and equipment under maintenance.

III.3 Production Platforms

III.3.1 Definition of Visited Facilities

In order to complete the objectives outlined in Section III.1 for production platforms, qualitative surveys were performed on various types of production platforms. Table III.5 summarizes the eleven platforms on which observations were made.

The equipment arrangement on the observed production platforms depended on the function of the platform. If the product from the wells was pumped directly to another platform nearby for separation, the only pieces of equipment present were the wellheads. For production platforms that separate the well product into its main components, the essential equipment systems observed were (1) the power generating system, (2) wellhead equipment, (3) hydrates prevention equipment, (4) preliminary separating equipment, (5) oil-water separating equipment, and (6) gas purification equipment.

Figure III.2 is a typical flow diagram for an oil and gas production platform with separation capabilities. The major pieces of equipment in each of the systems necessary to operation on this type of platform are summarized in Appendix D. The gaseous and particulate sources associated with this equipment will be discussed further in Section III.3.3.

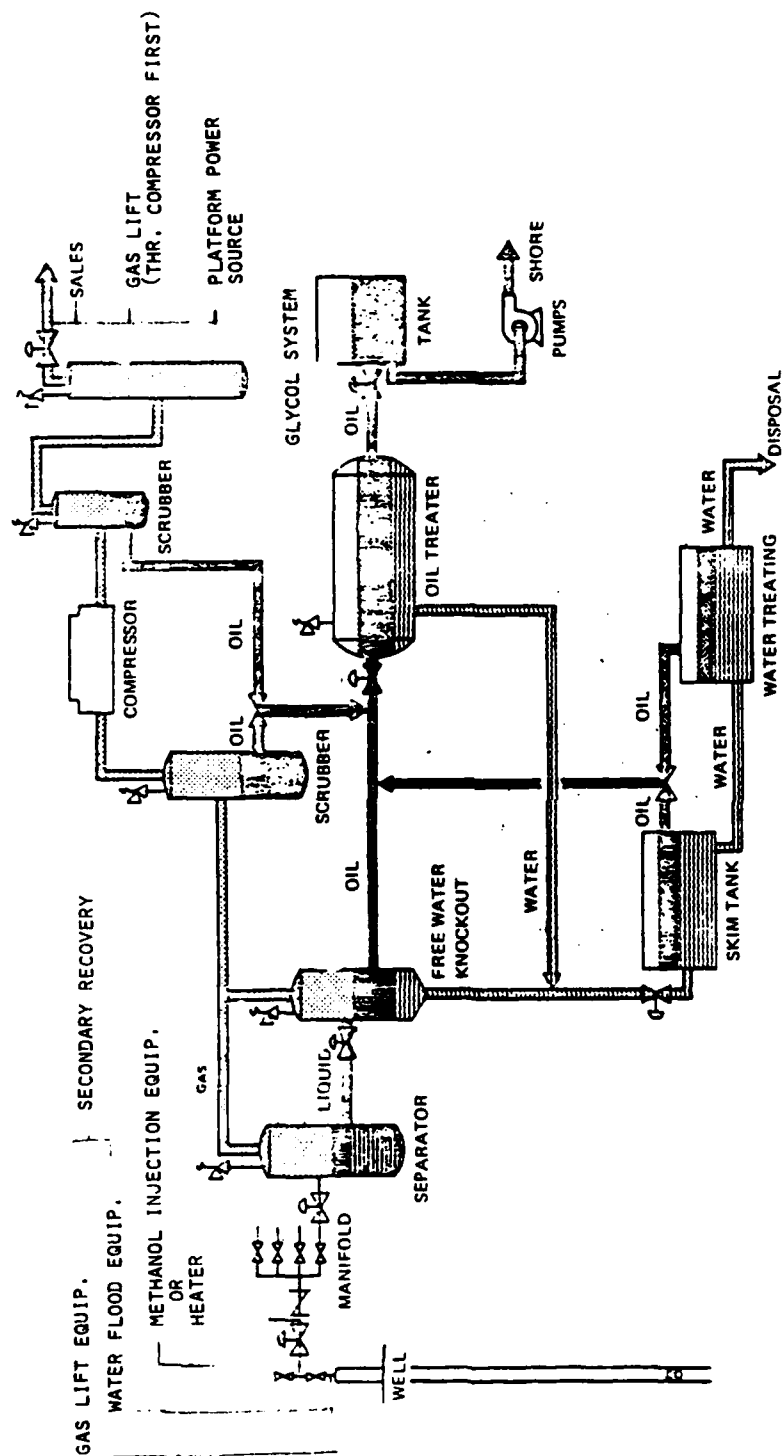
III.3.2 Worker Activities

Many types of workers are necessary for the operation of a manned, offshore platform with production and/or processing facilities. Table III.6 presents the categories and typical number of workers on these platforms. Table III.7 outlines their typical work activities and their potential exposures to contaminant sources during a working day.

The majority of the workers work a 7-day-on, 7-day-off, 12-hour/day schedule. Workers such as welders, mechanics, and electricians are available to service a number of platforms in a given area. The pumpers are assigned various unmanned platforms in the area which they must inspect daily to ensure proper functioning of equipment.

TABLE III.5. PRELIMINARY OFFSHORE OBSERVATIONS OF PRODUCTION PLATFORMS

Company	Platform Class	Operation
C	4-Pile Production + 4-Pile Compression Station	Production-Oil/Gas (gas lift)
	4-Pile Production with work over rig	Production-Oil/Gas (water flood)
D	16-Pile Package	Production-Oil/Gas
	8-Pile Package	Production-Oil/Gas
E	8-Pile Package	Oil/Gas Production
	8-Pile Production	Production-Gas
	8-Pile Production	Production-Oil/Gas
G	8-Pile Production	Production-Gas
	8-Pile Production	Production-Gas, Processing
	8-Pile Production	Production-Oil, Processing
	8-Pile Production	Production, Processing



Source: Paper by C.C. Taylor, Exxon Company, U.S.A., "Status of Completion/Production Technology for the Gulf of Alaska and the Atlantic Coast Offshore Petroleum Operations," presented at the Resources for the Future, Inc., seminar, Washington, D.C., Dec. 5-6, 1973, conducted for the Council on Environmental Quality under contract No. EQ4AC003.

FIGURE III.2. SIMPLIFIED SCHEMATIC FLOW DIAGRAM
FOR AN OIL AND GAS PRODUCTION PLATFORM

TABLE III.6. CATEGORIES FOR WORKERS ON PLATFORMS WITH
PRODUCTION AND/OR PROCESSING FACILITIES

Category	Typical Number
Pumpers	4
Foreman	1
Motorman	1
Galley Crew	2
Companyman	1
Welder	1
Roustabout Crew	3
Janitor	1
Mechanic	1
Electrician	1

TABLE III.7. WORKER ACTIVITIES ON PLATFORMS WITH PRODUCTION FACILITIES

Worker	Typical Work Activities	Potential Exposure to Contaminant Sources
Pumper	Maintains equipment to meet USGS regulation specifications.	Vapors and mists that may be in the air.
Foreman	Supervises and coordinates all activities on the platform.	Various vapors and skin contact while supervising operations.
Motorman	Checks operation of engines, generators, compressors, pumps, and other accessories. He checks lubrication oil and makes minor adjustments on the engines but no major repairs.	Vapors from machinery in various rooms in which he works. Oil mists from the machinery.
Galley Crew	Prepare meals and clean kitchen area.	Vapors that may be taken up in the air conditioning system.
Companyman	Oversees all work activities and communicates with the oil company for whom he works.	Various vapors and skin contact while supervising operations.
Welder	Repairs and fabricates metal structures on the platform.	Vapors and mists that may be in the air. Welding fumes.
Roustabout Crew	Handle routine maintenance necessary on the platform.	Vapors and mists that may be in the air.
Janitor	Maintains cleanliness in the living quarters.	Vapors that may be taken up in the air conditioning system.
Mechanic	Repairs the engines, compressors, generators, and pumps on the platform.	Vapors from machinery in various rooms in which he works. Oil mists from the machinery.
Electrician	Repairs faulty wiring of the equipment on the platform.	Vapors that may be in the air.

III.3.3 Identification of Contaminant Sources

From the preliminary observations on production platforms, it was concluded that the major exposure potentials for workers on these platforms is to gaseous hydrocarbon vapors, referred to as fugitive emissions, released from various sources.

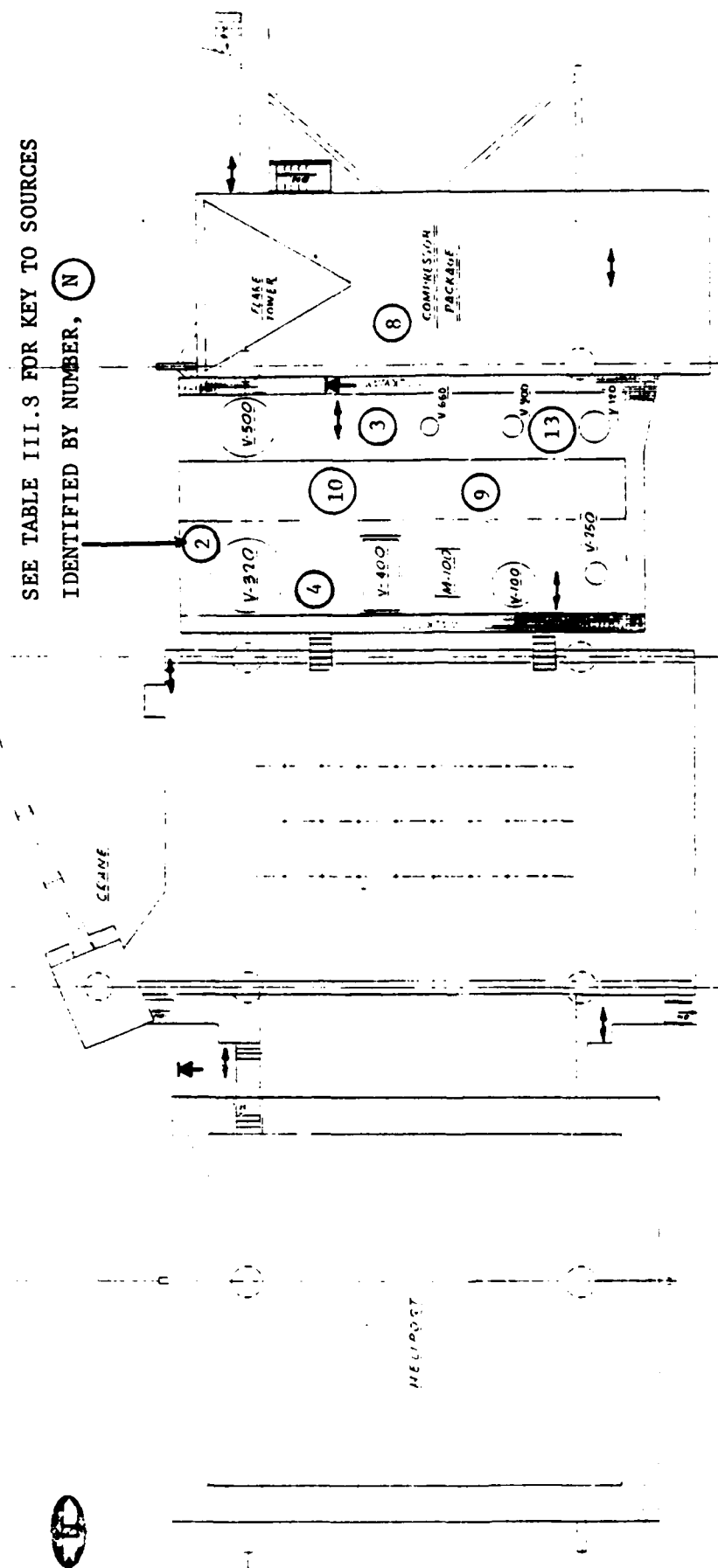
In order to identify the gas/vapor emission sources and to quantify the relative strength of the emissions, hydrocarbon concentration levels were measured during visits to three Company E platforms and three Company G platforms. An Organic Vapor Analyzer (OVA), which indicates a "total hydrocarbon" concentration as an equivalent concentration of methane, was used for vapor source measurements. Typical levels of background concentration were 5 ppm to 10 ppm as CH₄. However, concentration levels of 100 ppm and higher were not unusual near the emission sources. For illustration purposes, concentration values are shown superposed onto layout drawings of the upper and lower platform deck levels of a representative platform in Figures III.3 and III.4. Emission sources for all six platforms are shown in Figures III.3 and III.4 to illustrate the general location of hydrocarbon vapor emissions on production platforms. Table III.8 is a key to Figures III.3 and III.4 and identifies the general areas and measured concentration values where emission sources were found. The concentrations tabulated in Table III.8 represent the range of values measured on the composite of six production platforms. Thus, they are not representative of any one platform, but provide an overview of concentration values in the vicinity of typical production platform equipment. Most of the emission sources found on these platforms were leaks at flanges or valves, drip pans or drains, vents, and equipment under repair.

Leaking flanges and valves seemed to be the most common source of the higher total hydrocarbon concentration readings. Although the general background around wellheads was only 5-20 ppm, concentration at several wellhead flanges, shown in Figure III.5, reached 600 ppm. Concentrations at flanges on several P/V valves, shown in Figure III.6 were on the order of 200 ppm. Other flanges that emitted measurable vapor concentrations were at a pig launch (100-500 ppm), header (100-1,000 ppm), test tank (500-700 ppm), and a condensate pump (300-7,000 ppm), shown in Figure III.7. A concentration of greater than 10,000 ppm was detected at a valve in the gas supply line for the instrument control gas, shown in Figure III.8.

Measurable concentrations were also measured at drip pans, drains, and vents. The concentrations at several drip pans that contained liquid were on the order of 100-200 ppm. It was found that at a sump drain, shown in Figure III.9, and at the open top of a test tank, the concentration levels were higher than the maximum reading of 10,000 ppm on the OVA.

Vapor concentrations were also measured in the vicinity of operating equipment in the compressor room. The background concentration in the room was 100-400 ppm, and the concentration at the pressure gauges

SEE TABLE III.3 FOR KEY TO SOURCES
IDENTIFIED BY NUMBER, (N)



UPPER DECK

FIGURE III.3. UPPER DECK LAYOUT DRAWING OF GAS PRODUCTION
AND PROCESSING PLATFORM

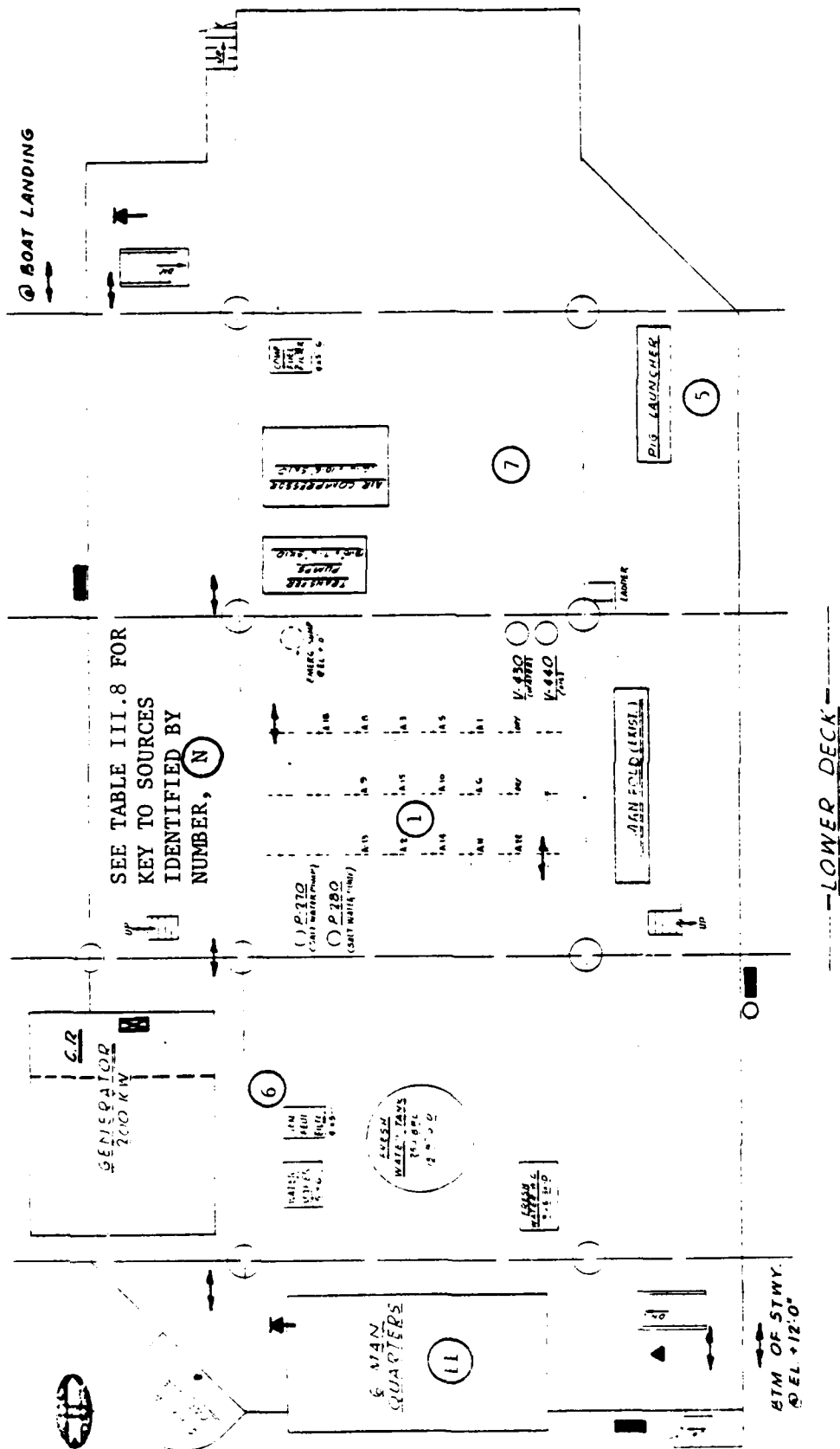


FIGURE III.4. LOWER DECK LAYOUT DRAWING OF GAS PRODUCTION AND PROCESSING PLATFORM

TABLE III.8. KEY TO FIGURES III.3 AND III.4

Location	Concentration (ppm CH ₄)	Remarks
① Wellhead	5 - 20	General background
	100 - 600	At several flanges
	> 10,000	Wellhead under service with leaking connection
② P/V valve	100 - 200	At several flanges
③ Test tank	> 10,000	Open vent on top
	500 - 700	At several flanges
④ Gas supply line for instrument control gas	> 10,000	At several valves - not present on platform with pneumatic instrument control
⑤ Pig launch area	100 - 500	At a flange
⑥ Generator fuel gas separator	100 - 150	At the drip pan
⑦ Wet oil tank	100 - 400	At vent
⑧ Compressor room	100 - 400	Background
	300 - 400	At pressure gauge
	1,000	At compressor
⑨ Oil skimmer	> 10,000	Open top, being serviced
⑩ Separator area background	20 - 100	
⑪ Living quarters	5 - 10	
⑫ Sump	> 10,000	At the drain
	700	At vent
⑬ Condensate pump	300 - 7000	

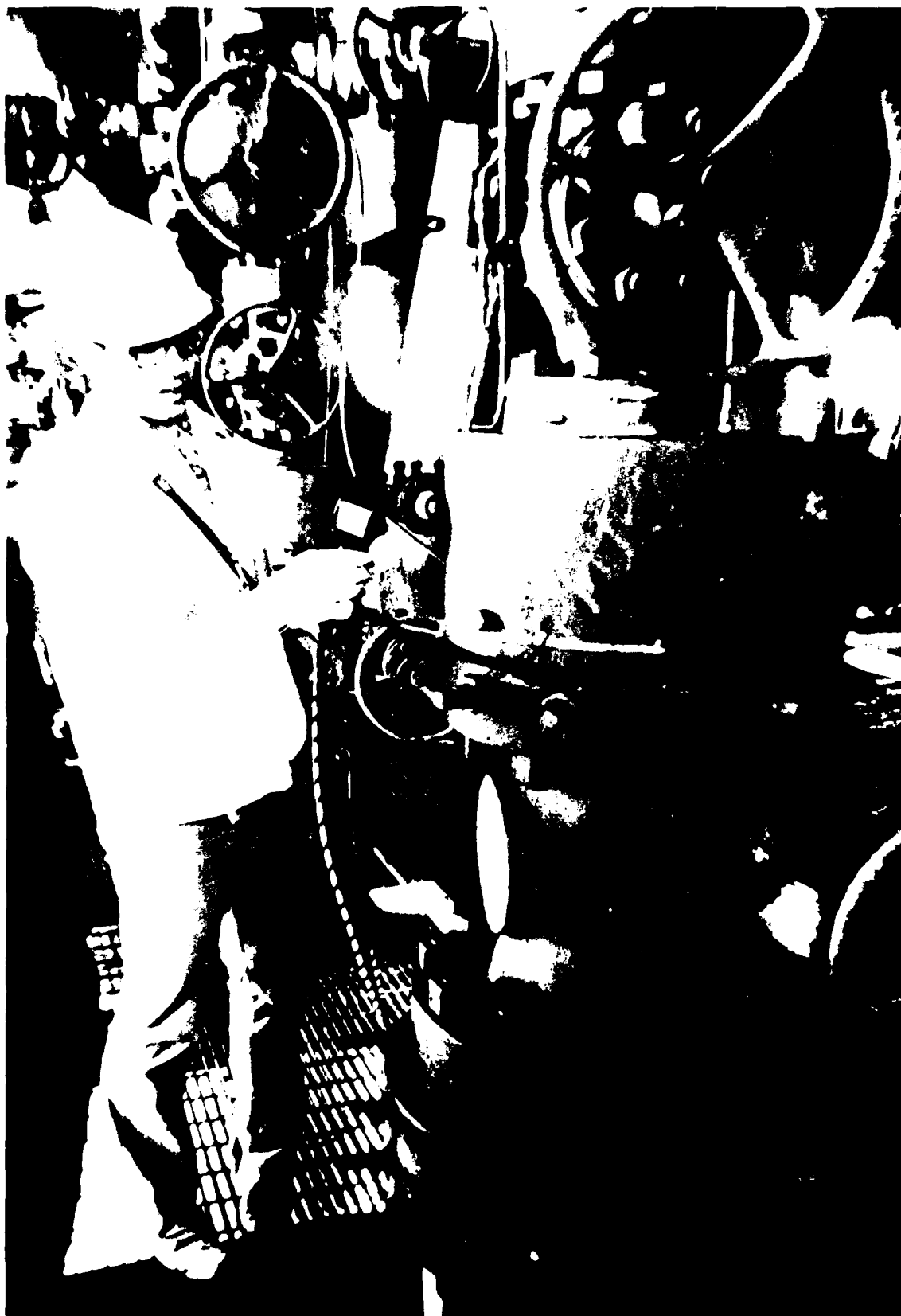


FIGURE III.5. MEASURING OF VAPOR CONCENTRATION WITH OVA AT LEADING WELLHEAD FLANGE



FIGURE III.6. MEASURING OF VAPOR CONCENTRATION WITH OVA AT A P/V VALVE FLANGE

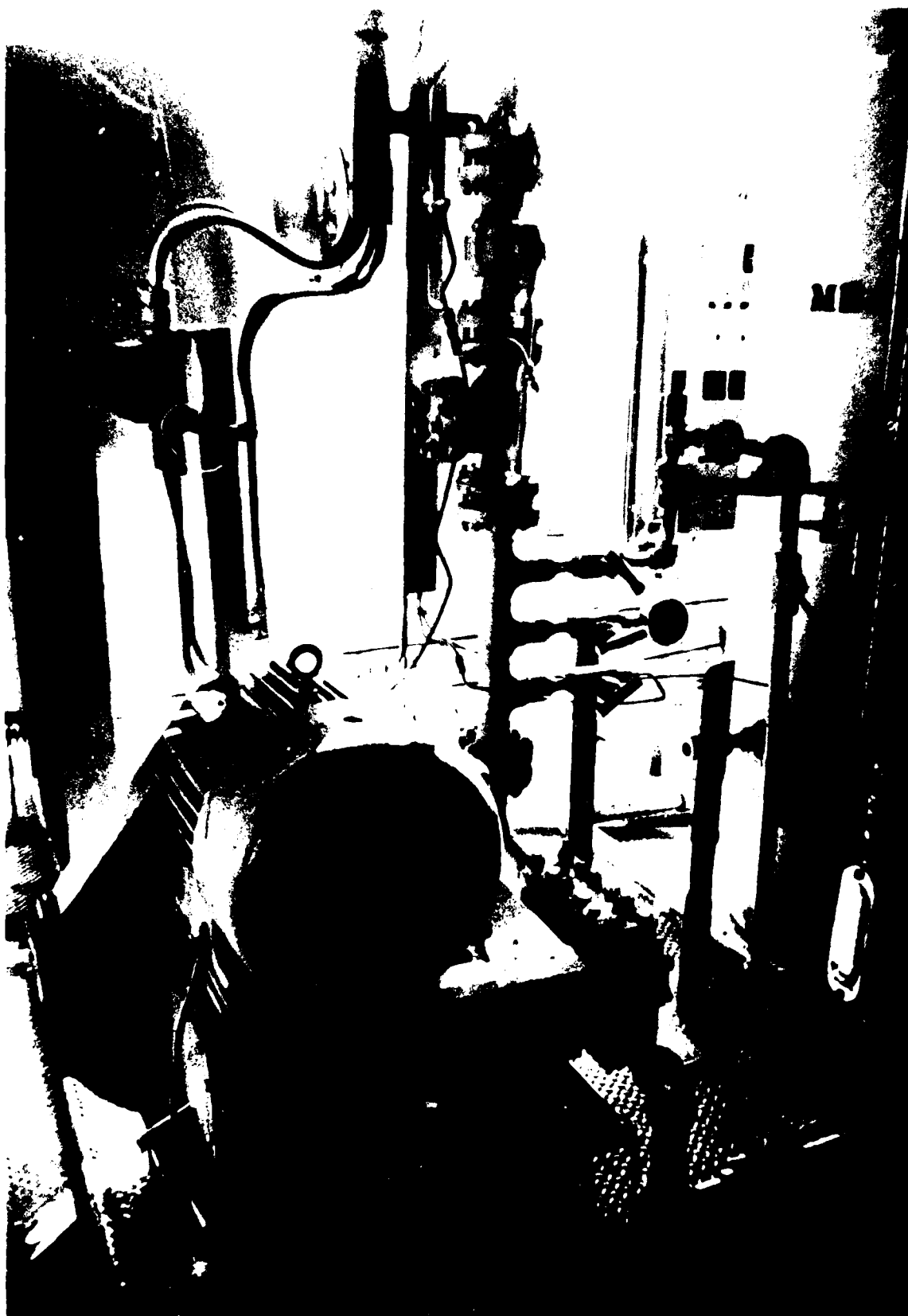


FIGURE III.7. CONDENSATE PUMP



FIGURE III.8. MEASURING OF VAPOR CONCENTRATION WITH OVA AT A VALVE IN THE GAS SUPPLY LINE
FOR THE INSTRUMENT CONTROL GAS

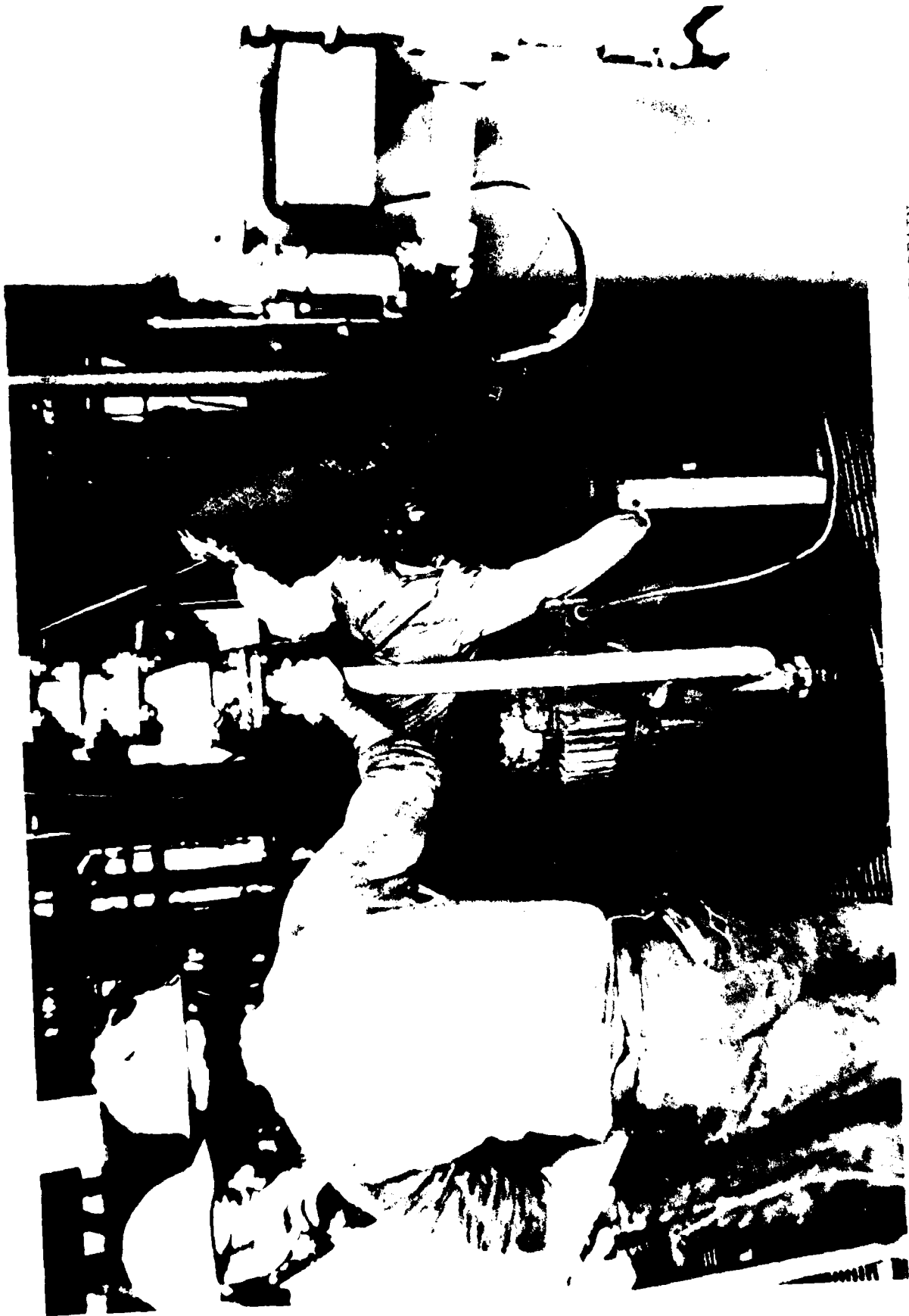


FIGURE III.9. MEASURING OF VAPOR CONCENTRATION WITH OVA AT A SUMP DRAIN

was 300-400 ppm, but those at the compressors were 1,000 ppm. The region surrounding the open top of the oil skimmer, which was under repair, was another area where the vapor concentration exceeded 10,000 ppm.

It is important to note that most regions of highest concentration were very localized, and the gas concentration level was diluted significantly within a few meters of the source. This signifies that the emission rates were probably low.

It is not possible to use the total hydrocarbon concentration readings as an indicator of occupational exposure because the chemical composition of the gaseous emissions and the corresponding occupational exposures are not quantified. Grab samples of gas and occupational exposures should be collected in those areas where the total hydrocarbon readings were highest for subsequent gas constituent analysis. Note that the C₁ through C₃ hydrocarbon gases are classified by the ACGIH as simple asphyxiants, not toxicants.

To summarize, the routine exposure potentials for workers on a platform with production facilities include inhalation exposure to vapors from chemicals being pumped or poured and inhalation exposure to gases from vents, leaking flanges, and valves. The non-routine inhalation exposures may occur during equipment maintenance.

III.4 Intermediate Measurements

Two intermediate visits to offshore drilling and production platforms were made to acquire more information regarding vapor sampling and analysis, and skin contact with drilling fluids. A complete trip report documenting these visits is contained in Appendix K. This section summarizes the results and conclusions.

III.4.1 Offshore Drilling Rigs

Visits were made to a semi-submersible platform drilling an exploratory well with water base mud, and to a platform/tender barge drilling a production well with oil base mud. The results may be summarized as follows:

- o Formation gases were released at the shale shaker when the water base mud returned gas-cut from the well drilled by the semi-submersible.
- o The shale shaker room on the semi-submersible platform had a large fan mounted into one wall that drew fresh air into the room and purged the formation gases from the room.
- o Gas concentrations in the shale shaker room do not exceed the maximum permissible levels allowed by current health and safety standards.

- o Dust from drilling fluid chemicals is emitted into the region of the mudman/pumper's work station when bags of chemical are added through the dry bulk hopper.
- o Workers have reported receiving burns from contact with caustic soda incurred during mud mixing operations.
- o Personal exposure sampling for respirable dust should be performed to determine whether dust masks or respirators are needed in the mud mixing room.
- o Skin contact with water base mud can be minimized by keeping the drill string, rotary table and drill floor clean and free of mud accumulation.
- o Vapor emitted from oil base mud at the shale shaker and in the mudpit room does not exceed the maximum permissible level allowed by current health and safety standards.
- o Vapors emitted from oil base mud in very hot weather, or from mud returning hot from deep wells, may be hazardous to workers if ventilation is inadequate to purge the vapors from work areas.
- o Drilling with oil base mud makes it difficult to keep the drill string, rotary table and drill floor clean and free of mud accumulation. As a result, the potential for skin and clothing contact with oil base mud may be greater than for water base mud.
- o Workers have reported developing skin irritation and rashes from contact with oil base mud and the detergents used to remove mud stains and deposits.

III.4.2 Offshore Production Platforms

A visit was made to an offshore production platform with oil/gas separation facilities and a high pressure gas compressor in operation. The results may be summarized as follows:

- o A great many fugitive emission sources were found including leaking flanges, valves, instrument gas connections. In most cases, the gas cloud resulting from these sources was rapidly diluted by the wind.

- o Gas chromatograph (GC) analysis of hydrocarbon gas and vapor samples was performed successfully on the platform itself. This method of analysis was recommended for use in later project tests.
- o GC Analysis of all source samples showed that the hydrocarbon concentration distribution was characteristic of natural gas with about 93 to 94% methane, and progressively smaller concentrations of other C₂ and C₅ hydrocarbons.
- o High gas concentrations were found in instrument panels at the dead oil transfer pump and in the high pressure compressor room. The use of natural gas as instrument gas produces high concentrations in the enclosed panel from fugitive emissions.
- o The presence of natural gas in the concentrations found on this platform does not constitute a health hazard by current standards.

IV. DEVELOPMENT OF EXPERIMENTAL PROGRAM

IV.1 Definition of Potential Hazards to be Investigated

The background study and preliminary platform observations on off-shore drilling rigs and production platforms provide the basis for a definition of potential hazard sources. The results presented in Chapter III show that gases, vapors and liquid sources can exist on both production platforms and drilling rigs, while mist and dust sources are usually confined to drilling (or workover) activities.

IV.1.1 Gases and Vapors

Gases and vapors from underground formations are sometimes found in the flow of drilling fluid that transports rock cuttings to the surface for removal. These formation gases, including hydrocarbon vapors and inorganic gases such as hydrogen sulfide, carbon dioxide, helium and nitrogen, may break out of solution from the drilling fluid at the shale shaker. Hydrogen sulfide is a gas of particular hazard as noted in Appendix J. Hydrogen sulfide is outside the scope of this project, however, since regulations pertaining to H_2S are the responsibility of the USGS. The hydrocarbon vapors range from simple asphyxiants, such as methane, ethane and propane, to substances with established threshold limit values (TLV) and short term exposure limits (STEL), such as butane, pentane, hexane and benzene. Whether or not the presence of these gases in the workplace constitutes a hazard depends upon their concentration in the air. The concentration level of gas near the shale shaker will depend upon the concentration of gas in the mud, the mud circulation rate and the fresh air ventilation arrangements near the shale shaker.

The drilling fluid may also emit a vapor into work areas near the mud pits and mud cleaning equipment. In the case of a water base mud, the vapor is mostly water vapor, which is not toxic. An oil base mud with diesel fuel as the oil phase can emit a "diesel fuel" vapor (actually a mixture of several hydrocarbon vapors) that may be irritating to the eyes or respiratory system.

On production platforms fugitive emissions of natural gas and crude oil vapors may be found in the wellhead area, around oil/water/gas and oil/water separators, from atmospheric vents on sumps, around gas compressors and near gas engines that are used as a power source for pumps and compressors. Natural gas emissions may also be discovered from instrumentation and flow controllers that use natural gas as an instrument air supply. Fugitive vapor emissions may also be released from drums of specialty chemicals (corrosion inhibitors, cleaning detergents, bactericides, anti-freeze additives) that are vented to the atmosphere.

IV.1.2 Dusts and Mists

Mists were seldom encountered during project observations on drilling rigs except for splash and spray from the vibrating screens on

the shale shaker. No mist emissions were found on production platforms. Airborne paint droplets during spray painting was observed and can occur on production or drilling platforms.

Dust emissions were observed during two operations. Fine particle dusts were produced in the drilling mud make-up area when barite and dry sacked chemicals were added to the drilling fluid through dry bulk hoppers. The amount of dust produced varied greatly with the fineness of the particles (for example, lignitic material was ground to a finer size than were the nut hulls and, therefore, produced more dust) and the technique used by the mudman in slitting and emptying the individual bags into the hopper. Dusts consisting of airborne silica particles were also produced during sandblasting of the offshore facility.

Some chemical drilling materials such as sodium hydroxide have a defined threshold limit value (TLV) or short term exposure limit (STEL) in milligrams/m³ for dust inhalation. However, TLV and STEL values have not been determined for most dry drilling mud ingredients. In this case, a total respirable dust concentration can be measured and compared with the 5 mg/m³ limit for nuisance particulate substances.

IV.1.3 Liquids

Some hazardous materials in liquid form have been observed on both drilling rigs and production platforms. For example, biocides containing acrolein are used to control the growth of microorganisms in oil field water systems, and methanol may be used to prevent freezing in fuel gas lines on production facilities. On drilling rigs, caustic soda (sodium hydroxide) is sometimes added as a liquid to the drilling fluid.

Liquids that come into contact with the skin may present a hazard. Some substances may produce irritation of the skin, while others could adversely affect health if absorbed through the skin. Skin contact with drilling fluids was not an uncommon observation. Workers can come into contact with the drilling fluid

- o on the drill floor when adding or removing lengths of drill pipe,
- o in the mud cleaning area during periodic measurements of drilling fluid properties, and
- o in the mud make-up area when adding liquid ingredients to the drilling fluid.

Whether or not skin contact with the drilling fluid produces a health hazard depends upon the nature and the amount of the chemical substances that are added to the mud. Substances which are believed to present a health hazard through skin contact have been identified in Section II.4.

IV.2 Analytical Modeling of Contaminant Emissions

Several analytical models are available that could be used to study the emission and dispersion of vapors from specific types of contaminant emission sources described in Section IV.1. There are several reasons for modeling the emission of vapors on offshore facilities:

- o to estimate the level of gas or vapor concentration in areas where men perform their work;
- o To estimate the size of the "cloud" of gas or vapor surrounding the emission point. In particular, to estimate the size of the cloud in which the concentration exceeds a recognized hazard criterion (LEL, TLV, STEL):
- o to determine the effect of modifying operational procedures or equipment geometry on the size and concentration level of the gas or vapor cloud.

IV.2.1 Applicability of Models

In situations where the emitted contaminant stream will be diluted and carried away by the wind, analytical modeling can give useful information to guide the experimental sampling plan. An "on-deck" plume dispersion model has been developed by SwRI* to simulate the dispersion of gases and vapors downwind of vents. This model is applicable to simulation of

- o fugitive gas or vapor emissions from leaking valves, flanges, vents, or P/V valves on offshore facilities.
- o exhaust gas streams from diesel or gas turbine stacks on offshore facilities.

However, the offshore observations reported in Section III showed that contaminant emission sources are often located in open or closed rooms. This includes

- o fugitive emissions from natural gas compressors in compressor rooms.
- o emissions of dust during loading of dry drilling fluid materials into hoppers in a mud makeup room.
- o emission of gas released from the drilling fluid at the shale shaker.

In these situations, the distribution of contaminant material is very dependent upon the combination of both natural and forced air circulation through the room. Except when the air circulation pattern is strongly controlled by a fan close to the emission source (see the discussion in

* "Investigation of the Hazards Posed by Chemical Vapors Released in Marine Operations-Phase I," Final Report, USCG Contract No. DOT-CG-70363-A, SwRI Project No. 02-4986, May 1979.

Section III.4.2), the air patterns will be unsteady and quite variable in time. While an attempt at modeling these situations could be made, it is unlikely that the predicted results would agree with the actual measurements which depend upon room geometry as well as the uncontrollable air circulation patterns.

Therefore, only the application of analytical modeling to fugitive emissions from equipment situated outdoors in the open air is of value.

IV.2.2 Outdoor Fugitive Emissions

Many of the contaminant emissions observed on offshore facilities can properly be called "fugitive" emissions. This term includes leakage of liquids, vapors or gases at flanges, valve stems, and threaded connections, as well as emissions from P/V valves and vents on sumps and tanks. One type of fugitive emission observed frequently on offshore production facilities is a leak of natural gas from a small diameter opening at a flange or threaded connection. A contaminant emission source of this type was chosen for modeling.

The following is a realistic example showing how vapor concentrations emitted from fugitive emission sources rapidly decay with distance away from the sources. The set of conditions selected for modeling are shown in Table IV.1. The emission rate of methane was estimated by assuming a choked, compressible flow of a perfect gas through an orifice. Three values of orifice diameter and three values of pressure drop across the orifice were selected. The mass flowrate through the orifice was calculated from

$$\omega = \sqrt{\frac{k}{R} \left(\frac{2}{k+1} \right)^{\frac{k+1}{k-1}}} \frac{\rho_0 \cdot A}{\sqrt{T_0}} \quad (\text{IV.1})$$

where

- ω = mass flowrate
- k = ratio of specific heats = 1.32 for methane
- A = area of orifice
- R = gas constant
- ρ_0 = stagnation pressure upstream of the orifice
- T_0 = stagnation temperature upstream of the orifice.

For a calculated value of flowrate, initial values of jet velocity, concentration and jet diameter are furnished to the plume dispersion model. The model solves a set of differential equations based upon the laws of conservation of mass, momentum and chemical species to estimate the growth of the plume (due to entrainment of air) in the downwind direction. The model includes the effects of atmospheric turbulence on

TABLE IV.1 CONDITIONS FOR FUGITIVE EMISSION MODEL
EXAMPLES

Fixed Conditions

- o Wind Speed: 2.2 m/s (5 mile/hr)
- o Ambient Turbulence: 20%
- o Gas Released: Methane at 70°F
- o Ambient Temperature: 294°K (530°R)
- o Ambient Pressure: 101.3 kPa (14.7 psi)
- o Height of Source: 1.68 m (5.5 ft)
- o Angle of Discharge: 0° (parallel to the wind, in the downwind direction)

Variable Conditions *

- o Equivalent Orifice: 0.40 mm (1/64 inch)
Diameter 0.79 mm (1/32 inch)
1.59 mm (1/16 inch)
- o Gas Pressure Drop: 138 kPa (20 psi)
Across Orifice 345 kPa (50 psi)
689 kPa (100 psi)

* The line pressures associated with offshore gas processing equipment range from atmospheric to about 1000 psi. However, leakage paths for fugitive emissions around flanges, threaded connections and valve stems (with properly compressed gaskets and packing material) are tortuous and quite small, 1/32nd inch diameter and less. The pressure of the leaking gas is decreased considerably as it passes along the leakage path. The set of variable conditions used here is meant to represent a range of conceivable release conditions at the end of the tortuous leakage path.

plume entrainment directly through the specification of wind turbulence level. The value of 20% turbulence was selected to give concentration field predictions that correspond to 10-minute, time-average values.

The results of the plume model predictions are shown in Figures IV.1 through IV.9. Figures IV.1, 2, and 3 show predicted concentration contours at a vertical height of 1.68 m (5.5 ft, even with the height of the emission source) for emission of methane from a 0.4 mm (1/64th inch) orifice and pressure differences across the orifice of 138 kPa, 345 kPa, and 689 kPa (20, 50, and 100 psi, respectively). Contours corresponding to 1000 ppm, 100 ppm, and 10 ppm methane are shown in the Figures. The methane emission rates are quite low for these examples, only 0.18 kg/hr, 0.34 kg/hr, and 0.61 kg/hr corresponding to the low, middle, and high values of stagnation pressure. Note that the 1000 ppm contour extends only to 0.3 m, 0.45 m, and 0.6 m downwind of the emission point. The region of flammable concentration, between 50,000 ppm and 150,000 ppm is confined to the region very close to the orifice and is too small to appear on this figure. However, concentrations as high as 10 ppm are expected to persist several meters downwind of the vent even for the lowest value of stagnation pressure. An Organic Vapor Analyzer (OVA) in the total hydrocarbon mode is sensitive to hydrocarbon gas and vapor concentrations in excess of 5 ppm. Therefore, a walk-through survey with an OVA should be able to detect the gas or vapor cloud that results from fugitive emissions. Once the cloud is detected, it is possible to track it back to its source by walking upwind in the direction of increasing concentration.

Figures IV.4, 5, and 6 show predicted concentration contours for methane emission from a 0.79 mm (1/32nd inch) orifice and the same three values of stagnation pressure. Methane emission rates are 0.73 kg/hr, 1.4 kg/hr, and 2.4 kg/hr, respectively. The region within the 1000 ppm concentration contour is still rather small, extending only to 0.65 m, 0.9 m, and 1.2 m downwind of the vent for the three different values of stagnation pressure.

Finally, Figures IV.7, 8, and 9 show predicted concentration contours for methane emission from a 1.6 mm (1/16th inch) diameter orifice. Methane emission rates are approximately 2.9 kg/hr, 5.5 kg/hr, and 9.7 kg/hr, respectively for the same three values of stagnation pressure. Although the gas clouds are significantly larger than in earlier examples, they are still relatively narrow in the crosswind direction in Figure IV.9; the maximum average width of the 1000 ppm contour is less than 1 meter. Note also that this figure indicates that the 100% methane gas cloud will be diluted by a factor of 1000 within a distance of 2.4 m (7.9 ft) from the source.

The results of this section suggest the following conclusions:

- o Although fugitive emissions are highly concentrated at the source, the emission rate is small and the

CONTOURS AT MAN BREATHING HEIGHT

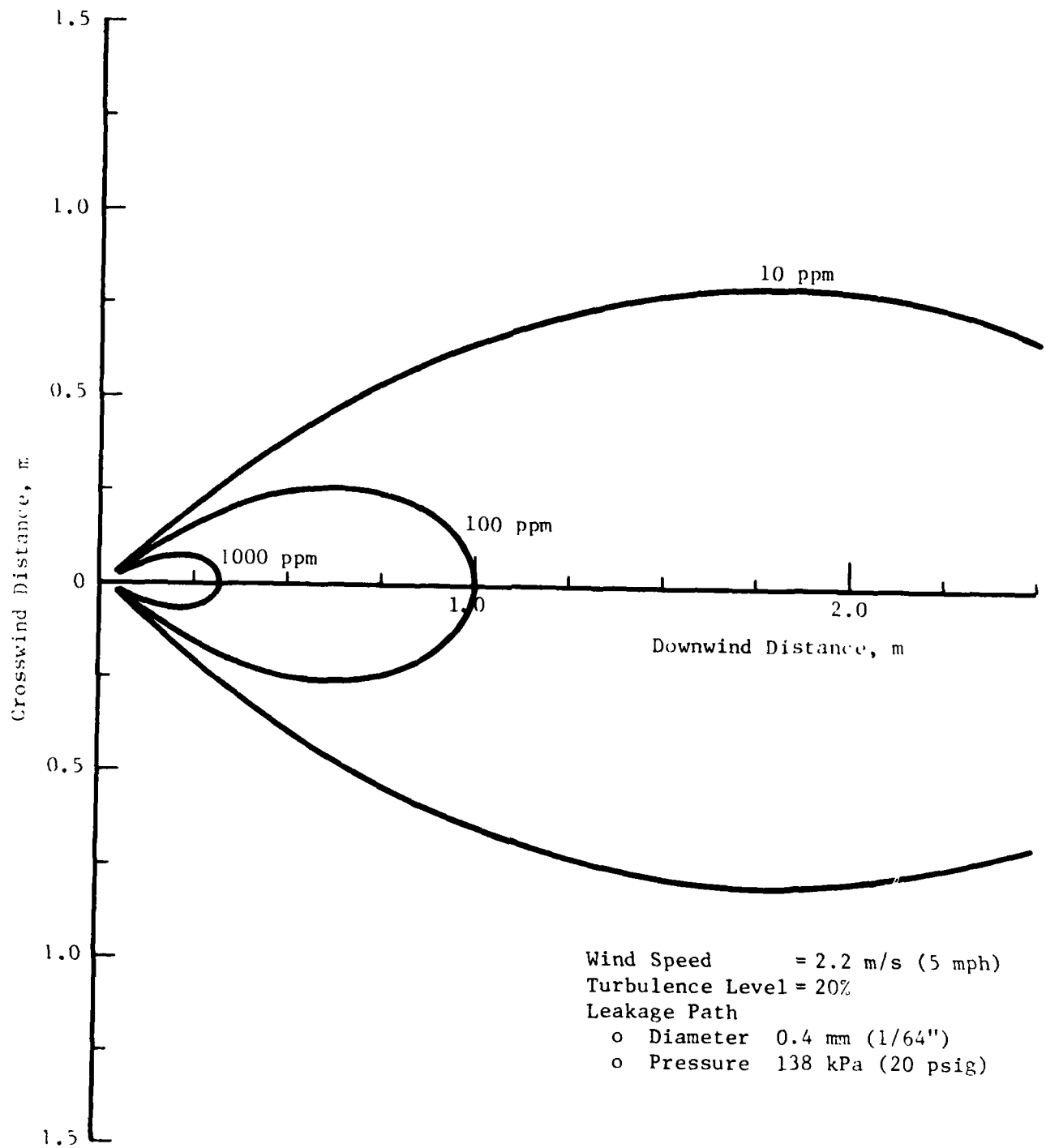


FIGURE IV.1. PREDICTED CONCENTRATION CONTOURS FOR
 FUGITIVE EMISSIONS OF METHANE,
 FOR A LEAKAGE PATH DIAMETER OF 0.4 mm AND EXIT PRESSURE OF 138 kPa

CONTOURS AT MAN BREATHING HEIGHT

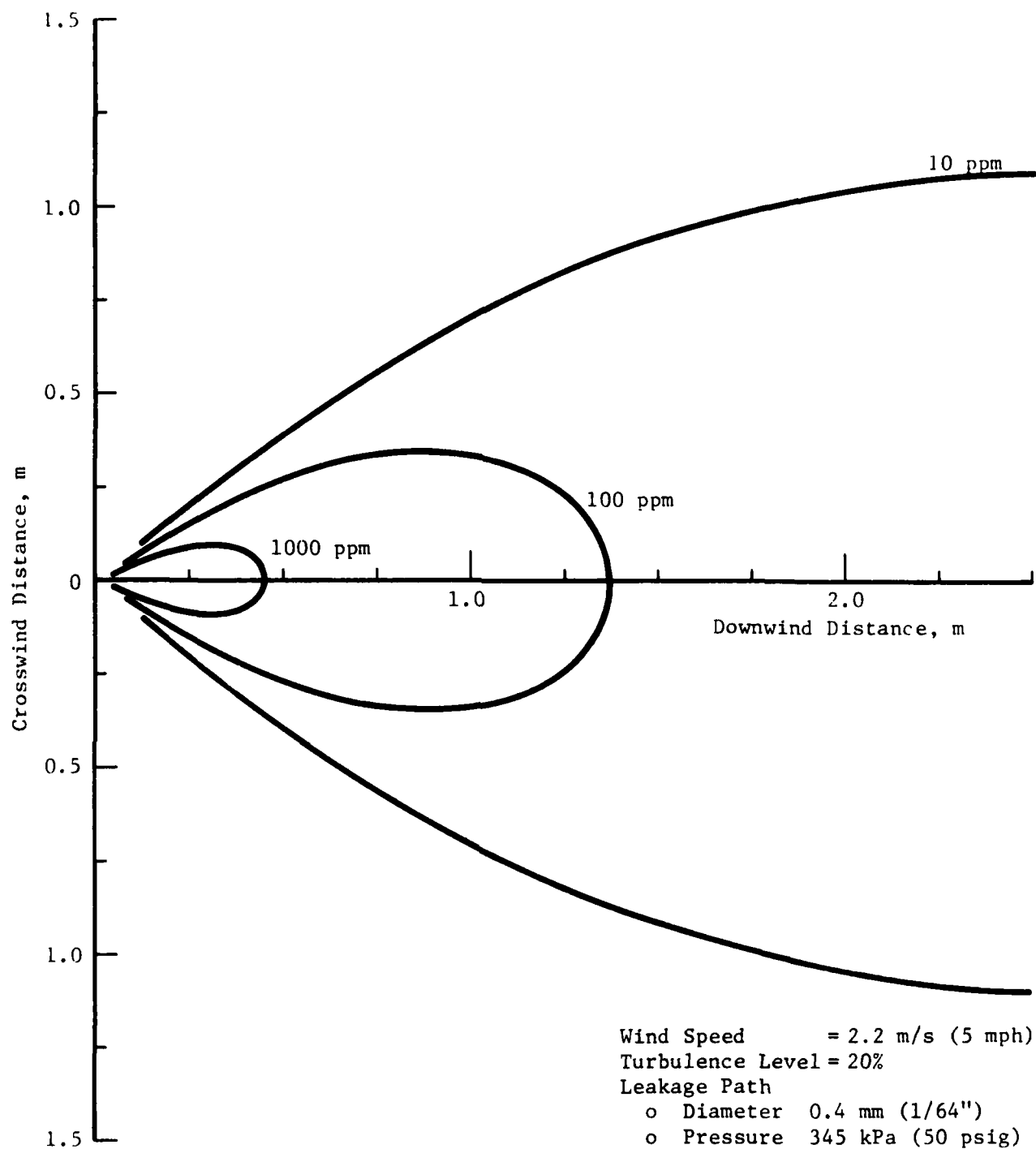


FIGURE IV.2. PREDICTED CONCENTRATION CONTOURS FOR
FUGITIVE EMISSIONS OF METHANE
FOR A LEAKAGE PATH DIAMETER OF 0.4 mm AND EXIT PRESSURE OF 345 kPa

CONTOURS AT MAN BREATHING HEIGHT

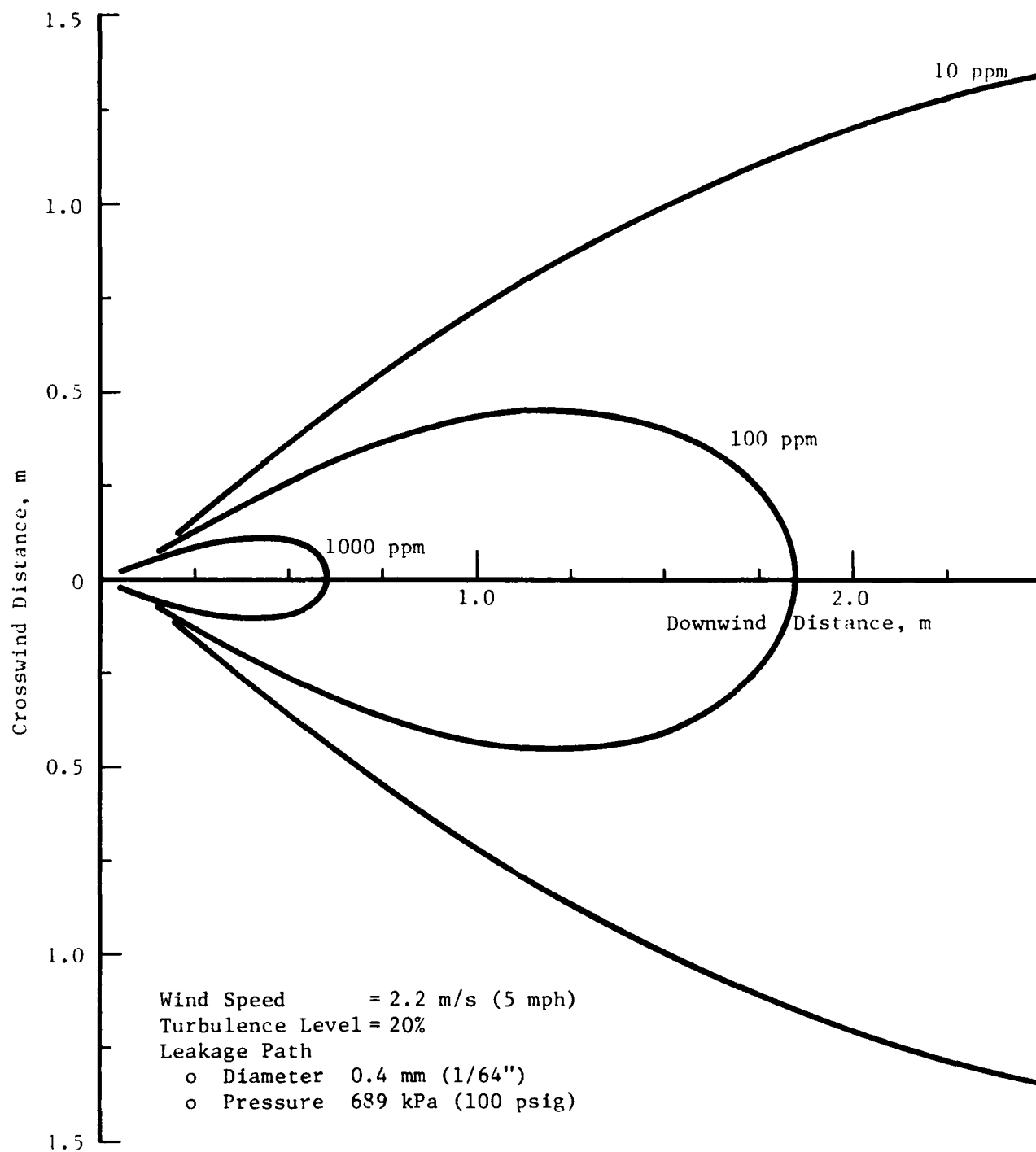


FIGURE IV.3. PREDICTED CONCENTRATION CONTOURS FOR
 FUGITIVE EMISSIONS OF METHANE
 FOR A LEAKAGE PATH DIAMETER OF 0.4 mm AND EXIT PRESSURE OF 689 kPa

CONTOURS AT MAN BREATHING HEIGHT

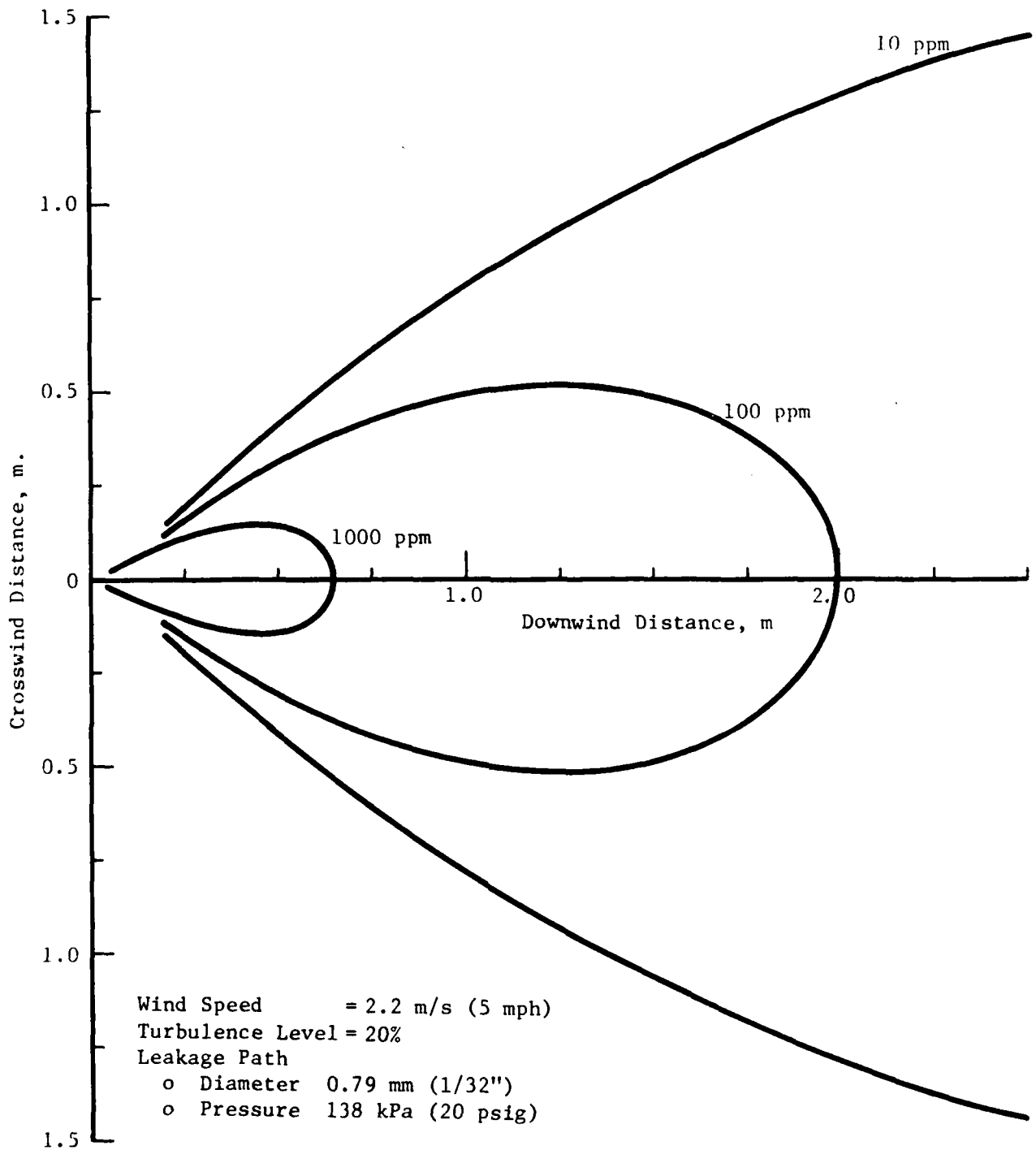


FIGURE IV.4. PREDICTED CONCENTRATION CONTOURS FOR
FUGITIVE EMISSIONS OF METHANE
FOR A LEAKAGE PATH DIAMETER OF 0.79 mm AND EXIT PRESSURE OF 138 kPa

CONTOURS AT MAN BREATHING HEIGHT

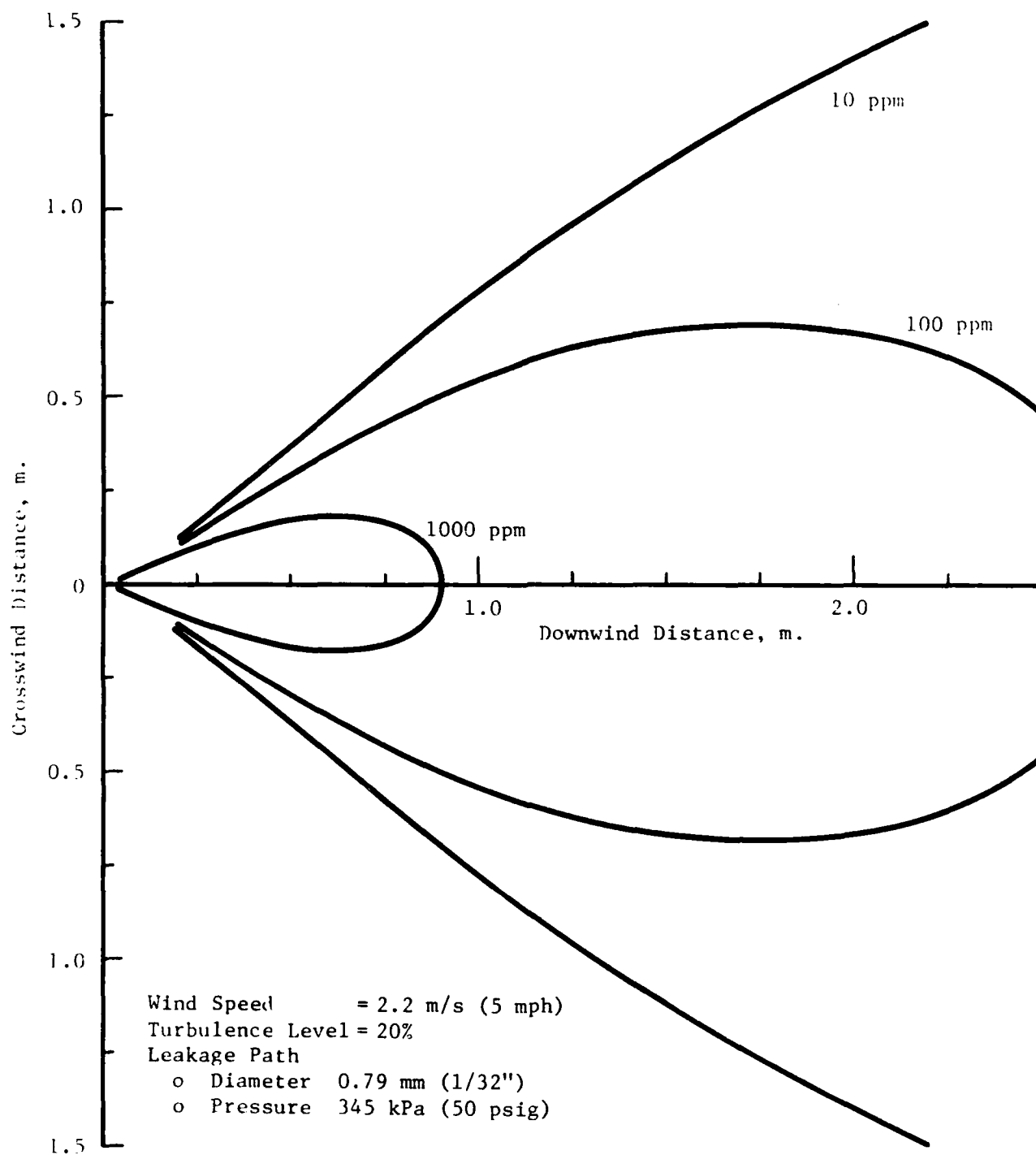


FIGURE IV.5. PREDICTED CONCENTRATION CONTOURS FOR
FUGITIVE EMISSIONS OF METHANE
FOR A LEAKAGE PATH DIAMETER OF 0.79 mm AND EXIT PRESSURE OF 345 kPa

CONTOURS AT MAN BREATHING HEIGHT

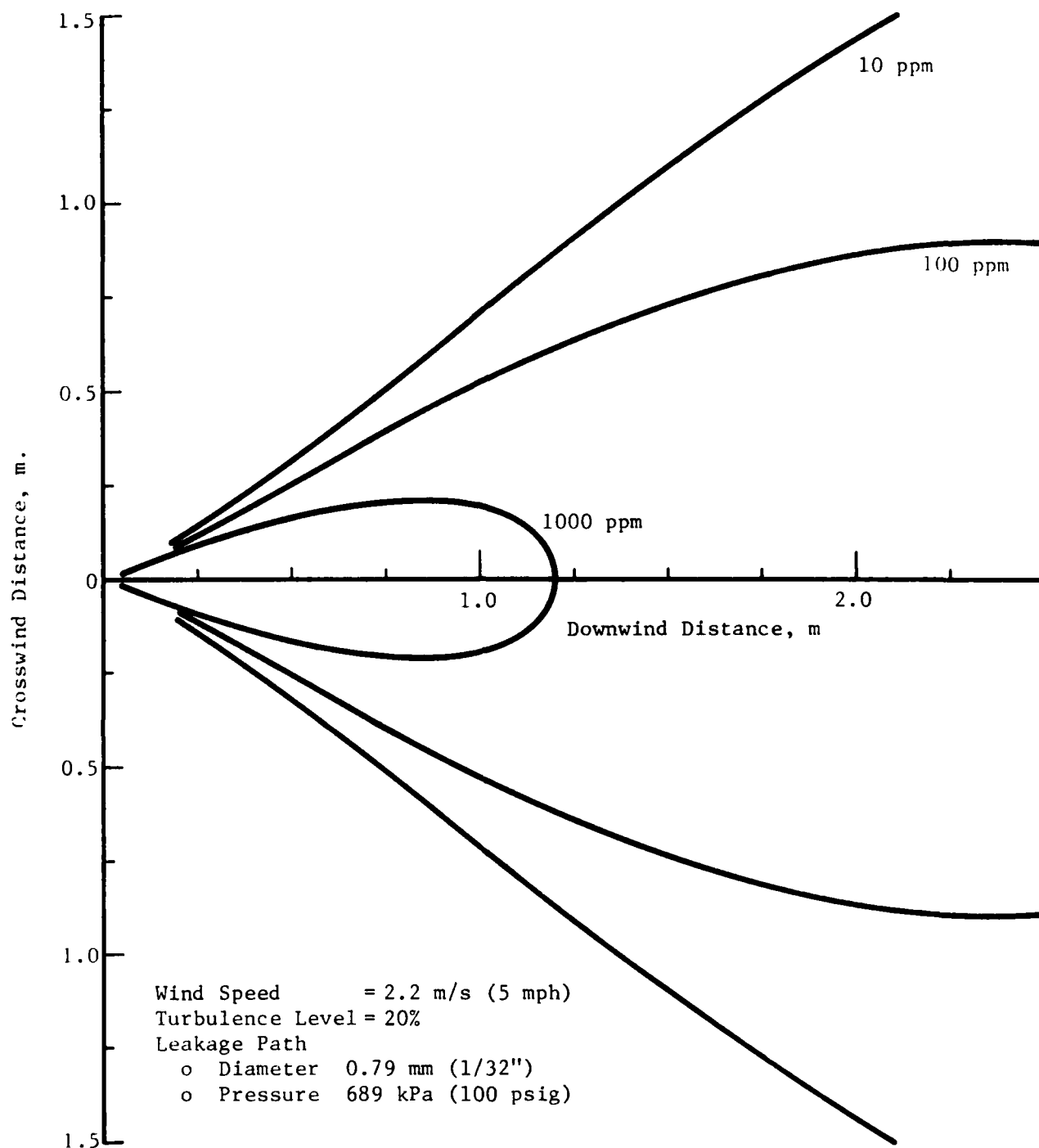


FIGURE IV.6. PREDICTED CONCENTRATION CONTOURS FOR
 FUGITIVE EMISSIONS OF METHANE
 FOR A LEAKAGE PATH DIAMETER OF 0.79 mm AND EXIT PRESSURE OF 689 kPa

CONTOURS AT MAN BREATHING HEIGHT

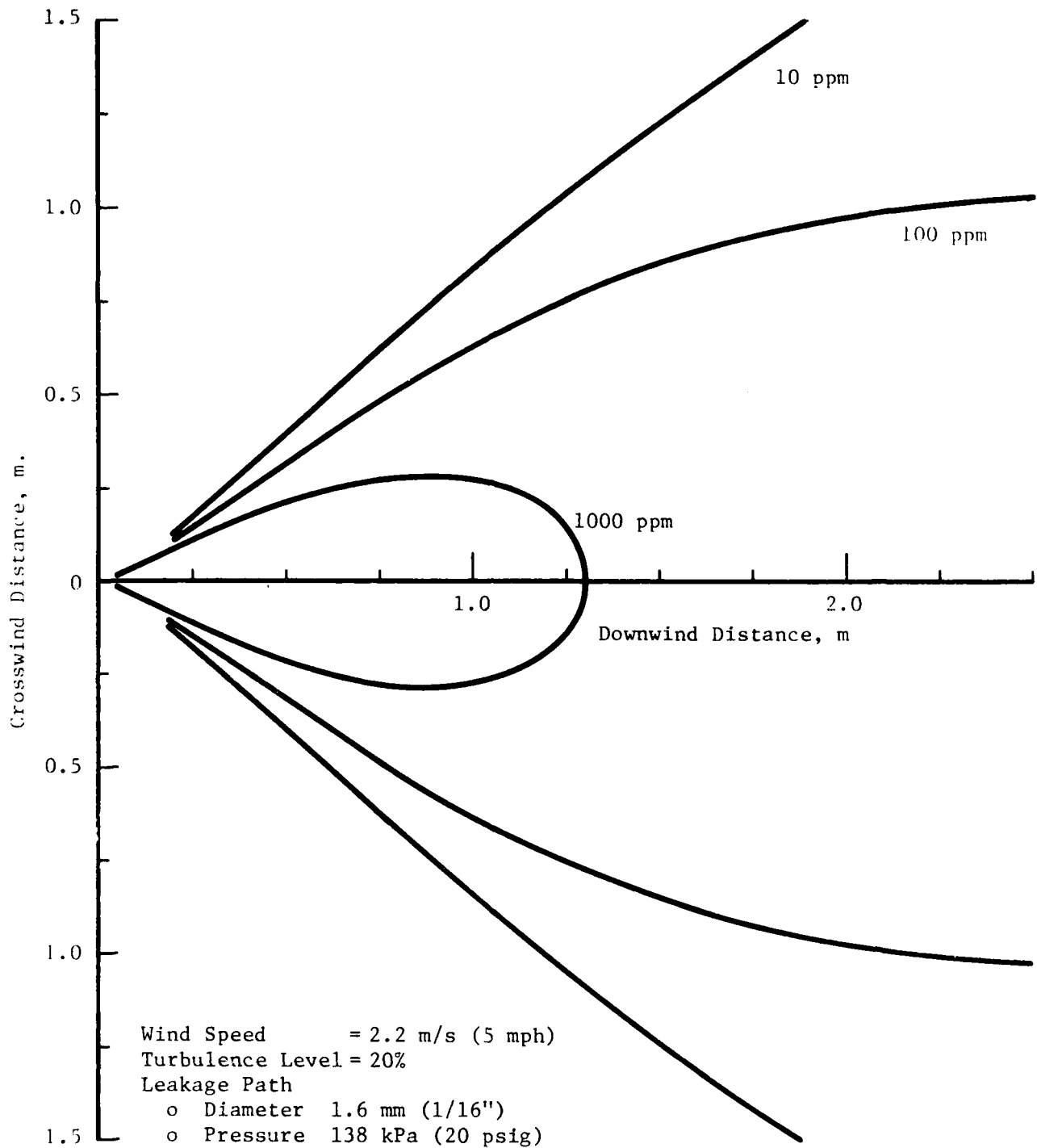


FIGURE IV.7. PREDICTED CONCENTRATION CONTOURS FOR
 FUGITIVE EMISSIONS OF METHANE
 FOR A LEAKAGE PATH DIAMETER OF 1.6 mm AND EXIT PRESSURE OF 138 kPa

CONTOURS AT MAN BREATHING HEIGHT

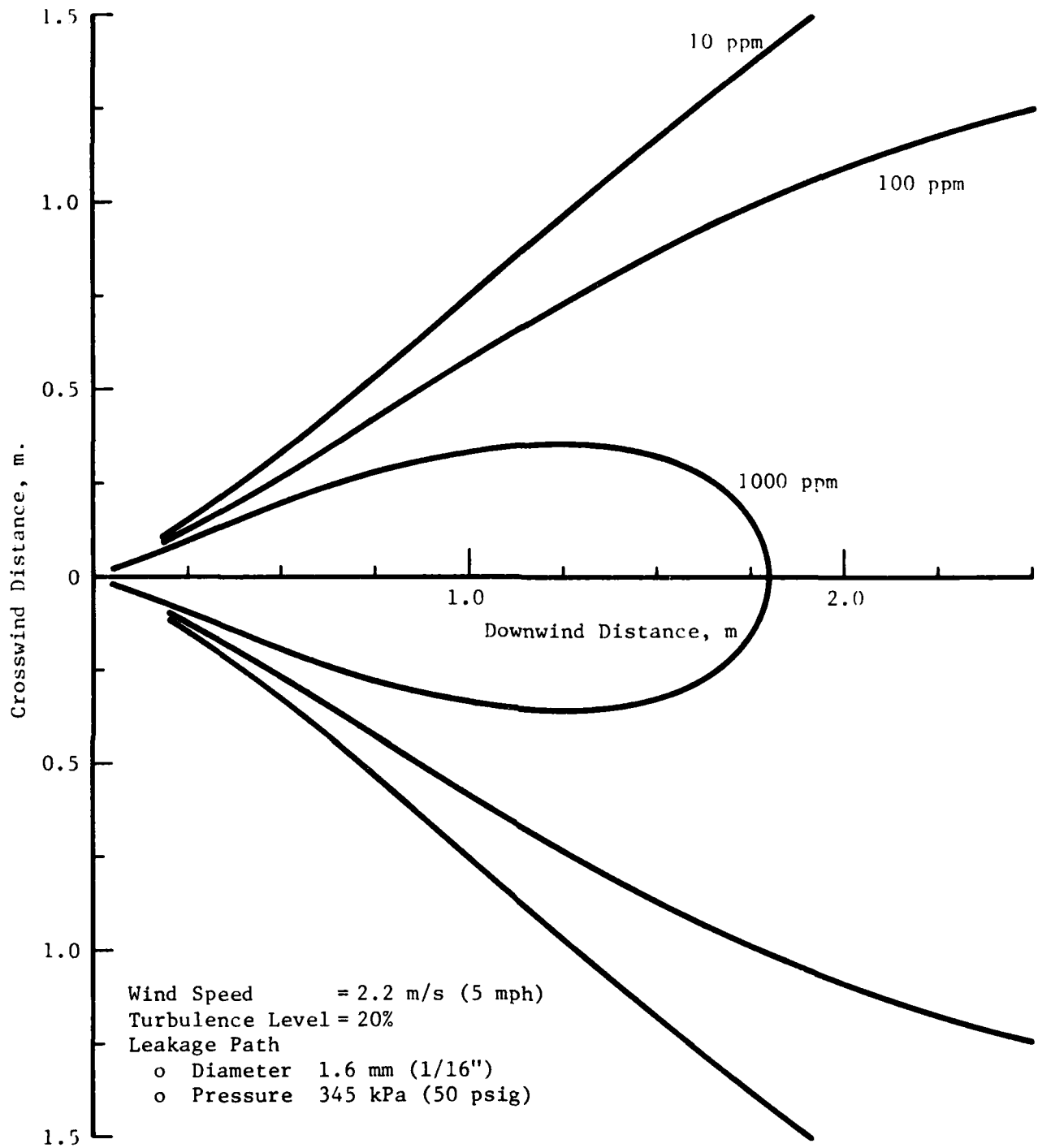


FIGURE IV.8. PREDICTED CONCENTRATION CONTOURS FOR
 FUGITIVE EMISSIONS OF METHANE
 FOR A LEAKAGE PATH DIAMETER OF 1.6 mm AND EXIT PRESSURE OF 345 kPa

CONTOURS AT MAN BREATHING HEIGHT

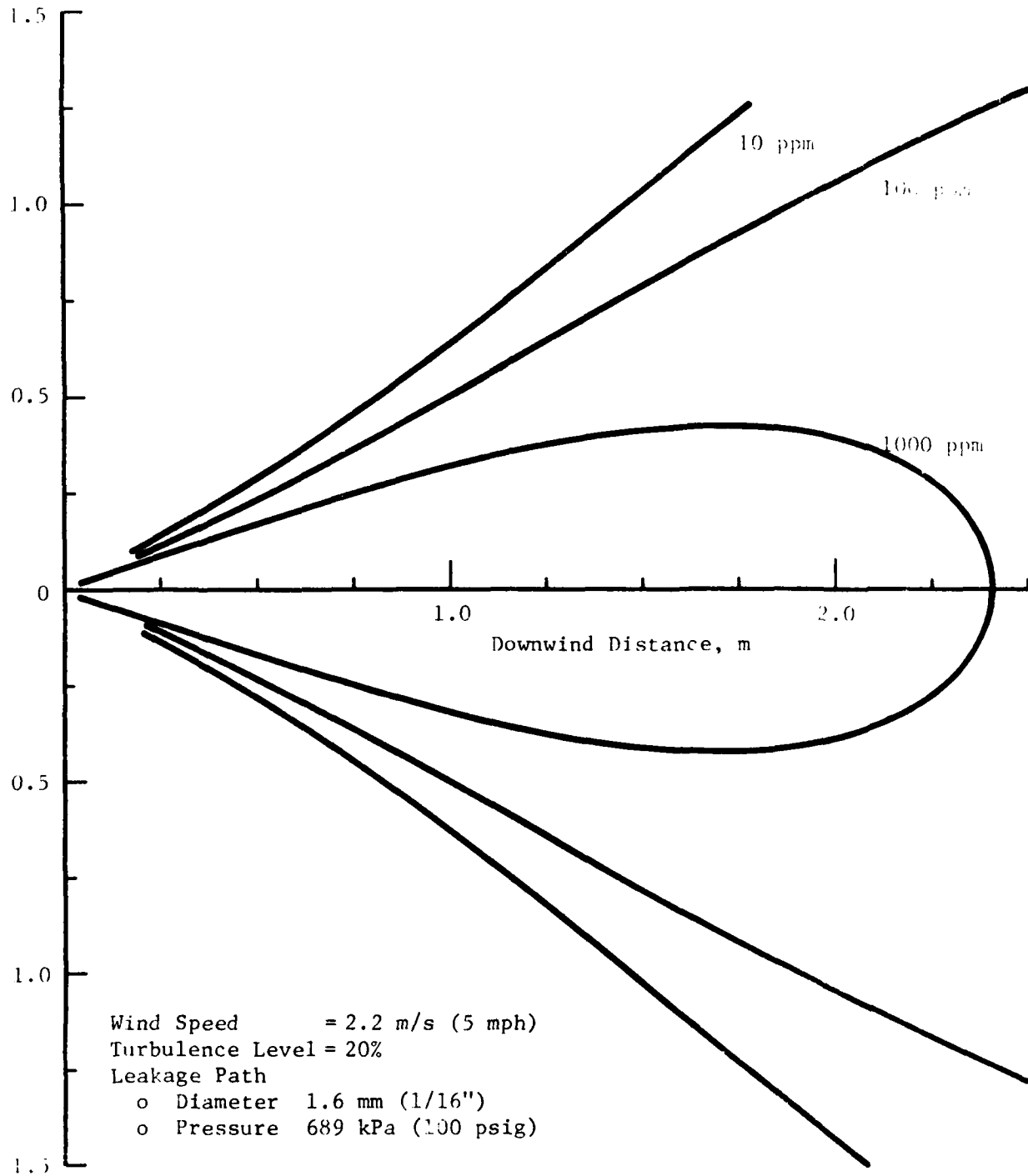


FIGURE IV.9. PREDICTED CONCENTRATION CONTOURS FOR
 FUGITIVE EMISSIONS OF METHANE
 FOR A LEAKAGE PATH DIAMETER OF 1.6 mm AND EXIT PRESSURE OF 689 kPa

emitted gas cloud will be diluted rather quickly by the wind.

- o The spectral volume containing flammable concentrations of gas and vapor from fugitive emissions will be relatively small and confined to the region close to the emission source.
- o A gas or organic vapor detector, sensitive to concentrations as low as 5 ppm (total hydrocarbon) will be very useful in detecting the presence of fugitive emissions and identifying the exact emission source.
- o Since fugitive emissions produce a spatially localized vapor cloud, it is questionable whether they will lead to significant gas concentrations in work areas unless
 - several emission sources are present simultaneously, or
 - ventilation (and dilution by the wind) is restricted by a barrier or enclosure.

IV.3 Experimental Methodology

IV.3.1 Gases and Vapors

Emission sources of organic vapors and gases can be located quickly with a portable Organic Vapor Analyzer. A Century Systems Dual-Mode OVA provides this capability and has sufficient accuracy to perform the measurements. It can be operated in either a total hydrocarbon or gas chromatograph mode. This type of instrument is certified for use in Class 1, Division 1, Groups A, B, C, and D hazardous areas. In the "total hydrocarbon" mode, it gives a continuous, direct readout of total organic vapor concentration for area surveys. This feature is particularly useful for walk-through area surveys in tracking an organic contaminant gas or vapor cloud back to its source. Figure IV.10 shows an Organic Vapor Analyzer being used during an area survey.

Once a contaminant emission source is identified, it is necessary to characterize the source constituents and concentration distribution. For this purpose, the source gas or vapor sample can be drawn through a sampling pump (MSA Model S, for example) and collected in an inert collection bag. The contents of the collection bag are then analyzed by a gas chromatograph. As discussed in Section IV.5, the emission sources on offshore oil and gas drilling and production facilities are expected to consist mainly of natural gas and crude oil vapors. To separate these constituents, an appropriate column must be used with the chromatograph.

For flame-ionization chromatographs, the contents of a source sample collection bag may be too concentrated and may cause a flameout of the flame ionization detector. If a flameout does occur, a secondary sample diluted 1:100 can be prepared by mixing gas from the source collection bag with ambient air in another inert bag.

To assist in the identification of individual peaks in the GC trace for the source sample gas, a "Mini-Mix" * calibration gas sample can also be analyzed offshore. An example of a calibration gas containing known concentrations of the gases and vapors is shown in Table IV.2.

TABLE IV.2 "MINI-MIX" CALIBRATION GAS

Gas	Concentration (ppm)
Methane	1154
Ethane	1469
Propane	1293
Isobutane	1372
Normal-butane	1049
Isopentane	1113
Normal-pentane	1009
Iso hexane	1162
Normal-hexane	1143

* Scientific Gas Products, Inc., Sample M1064.

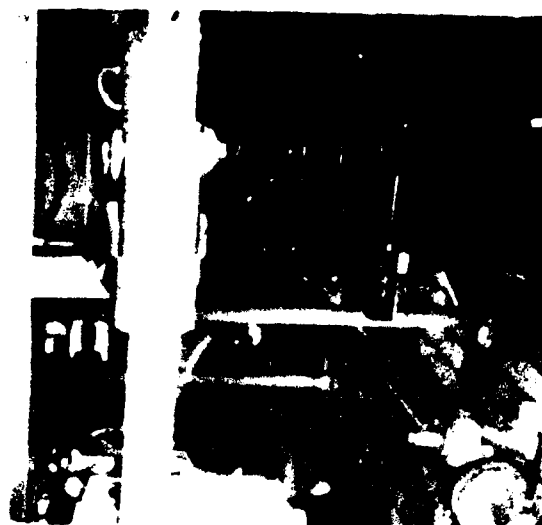


Figure IV.11 shows a sample GC trace obtained for the calibration gas sample. The GC trace for the calibration gas sample is then compared with the trace for the source sample gas to identify peaks with the same elution time as peaks in the calibration gas. When peaks are found that are not present in the calibration gas, samples of possible contaminants and/or liquid source samples can be taken for further peak identification tests, and laboratory analysis.

Area sampling for gases and vapors is performed in a similar manner as source sampling. An inert collection bag is attached to a sampling pump (MSA Model C-200, for example), and a gas sample is collected in the bag for a period of 10 minutes. Area samples should be collected at man breathing height, or about 1.68 m, by mounting the sampling pump and collection bag on a tripod as shown in Figure IV.12. The contents of the sample collection bag are analyzed with a gas chromatograph.

Personal sampling for gases and vapors is usually accomplished by drawing air samples from the worker's breathing zone through charcoal sampling tubes for a fixed period of time. Organic vapors present in the airstream may be adsorbed onto the charcoal. After exposure, the charcoal tube is returned to the laboratory and any chemicals present are desorbed from the charcoal and analyzed to determine a time weighted average concentration. Unfortunately, it is not possible to use charcoal tubes to collect many of the gases and vapors (in particular, methane, ethane, propane and butane) that are known to be present in contaminant emission sources on offshore oil/gas drilling and production facilities. If the area sampling results indicate that crew workers are likely to be breathing air containing significant concentrations of these gases, then another procedure can be implemented. Short duration (approximately 10 minute) samples of the air in a worker's breathing zone (drawn through a pump and collected in an inert sample collection bag) should then be analyzed by a gas chromatograph. These personal sample results can then be related to the results of the source and area gas and vapor sampling activities. If the GC traces from source and area samples indicate the presence of a chemical vapor other than methane through butane, then charcoal tubes should be used for personal sampling.

IV.3.2 Dust

Personal sampling of the respirable dust level is accomplished by drawing a continuous stream of air through a miniature cyclone assembly fitted with a 0.8 μ membrane filter. The cyclone separator and membrane filter assembly is attached to the worker's lapel by an alligator clip. Air from the breathing zone is drawn through the cyclone assembly by a pump adjusted to give a volume flowrate of about 1.7 liters/minute with the cyclone assembly attached.

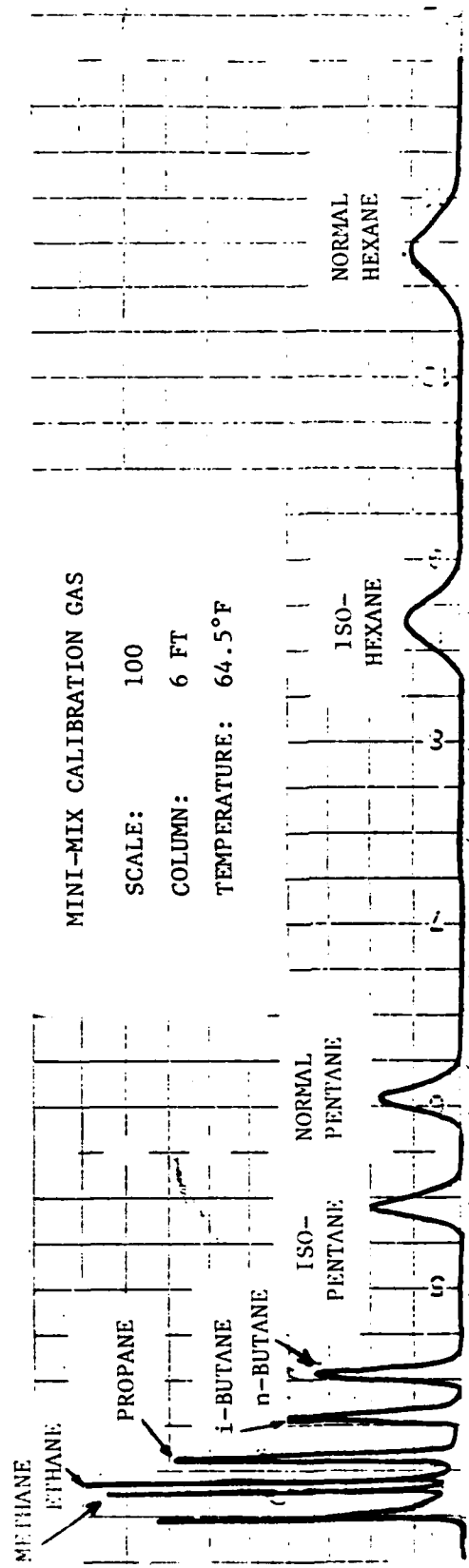


FIGURE IV.11 GC TRACE FOR CALIBRATION GAS SAMPLE

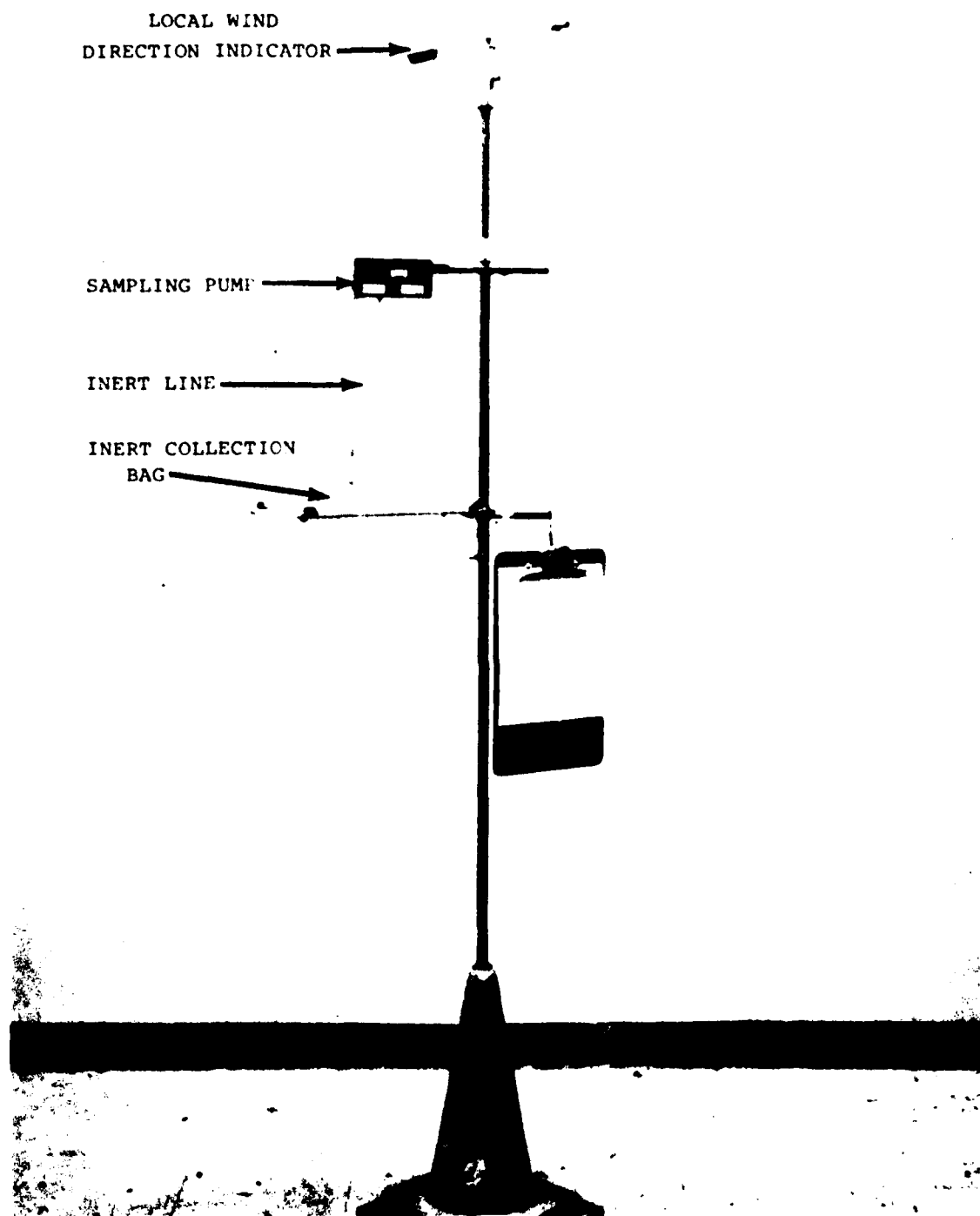


FIGURE IV.12. AREA SAMPLING APPARATUS FOR GASES AND VAPORS

The arrangement of pump and cyclone assembly is shown in Figure IV.13.

The individual membrane filters are weighed both before and after exposure to the dusty environment. The average dust concentration can be determined from the increase in weight, the volumetric flowrate of the pump, and the time of exposure.

$$C = 1000 \frac{\Delta W}{Q \Delta t} \quad (\text{IV.2})$$

where

- C = average dust concentration, mg/m³
- ΔW = increase in weight after exposure, mg
- Q = volumetric flowrate of the pump, liters/min
- Δt = time of exposure to dusty environment, min.

As an example, suppose that the weight of a filter membrane is increased by 0.85 milligrams after 100 minutes exposure to an airstream with a flowrate of 1.7 liter/minute, the respirable dust concentration level is 5 mg/m³.

If required, the nature of the particles can be identified by the use of atomic adsorption and/or gas chromatography after the particles have been separated from the filter membrane in the laboratory.

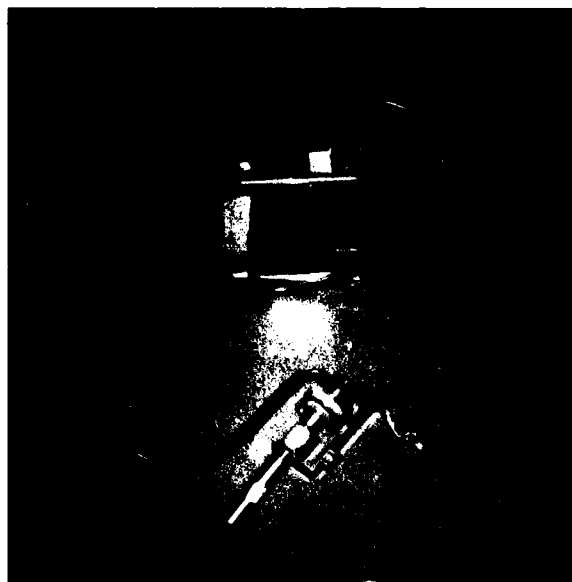


FIGURE IV.13 ARRANGEMENT OF SAMPLING PUMP
AND CYCLONE ASSEMBLY FOR DUST SAMPLING

IV.3.3 Liquid Contact with Skin and Clothing

A thorough documentation of dermal (skin) exposure should be carried out. In particular, documentation should seek to provide information concerning

- o the identity of the liquid in contact with the skin and possible irritants contained in the liquid,
- o the location and approximate area of skin or clothing in contact with the liquid,
- o the duration of contact, and,
- o personal hygiene and protective equipment.

Where possible, documentation should also include photographs.

IV.4 Final Experimental Plan

The experimental plan described in this section is designed to be implemented during a seven-day-long observation on an offshore drilling rig and/or an offshore production platform.

Offshore workers generally work a series of seven consecutive twelve-hour days, followed by seven consecutive days of rest on shore. As has been observed and reported in Section III, the operations on a drilling rig may vary from drilling to pulling pipe during a trip for a bit change from one day to the next. When an observation of worker activity during a particular operation is required, it may be necessary to spread the observation across two consecutive twelve-hour shifts in order to see all of the usual activities.

On production platforms conditions are less likely to change from day to day. Many of the typical sources of contaminant emission are properly called "fugitive emission" sources. They correspond to leaks at flanges, emissions from vents, or across gaskets. The emission sources can be located and area samples of vapor or gas concentration can be taken on any given day.

Therefore, the sampling plan described here is designed to be flexible. A set of key activities is outlined. However, the order in which they are performed could vary depending upon the state of operations on the offshore facility. The experimental sampling plan involves these six activities:

- o Identification of aerosol (dust, mist, vapor and gas) contaminant emission sources, and operations that involve skin contact with potentially hazardous liquids.
- o Characterization of the chemical composition and strength of the contaminant sources.

- o Area sampling for aerosols in work areas and living accommodation areas.
- o Observation and documentation of skin and clothing contact with drilling fluids and other liquids during work activities.
- o Documentation of work activities and personal sampling for exposure to aerosols for selected offshore workers.
- o Interpretation of the results of source, area and personal sampling data with respect to existing standards for industrial hygiene.

The experimental sampling plan should be implemented during a full seven-day observation of drilling rig and/or production platform operations on offshore facilities. Each of the six activities is described in more detail in the following sections.

IV.4.1 Source Identification

The first step involves locating and identifying contaminant emission sources and activities that may involve skin contact with potentially hazardous liquids. This is accomplished by a walk-through survey of all areas on the drilling rig and/or production platform.

Significant dust and mist emission sources can be identified visually. Likewise, activities that involve skin contact with drilling fluids and other liquids can be identified visually. However, vapor and gas emission sources are generally not visible. These should be identified using a portable gas chromatograph operating in the total hydrocarbon mode, as described in Section IV.3.1.

The walk-through survey for source identification should be conducted during the first day of the observation. It will be reported whenever operational conditions change.

IV.4.2 Source Characterization

Characterization of a source involves determining the chemical composition of the contaminant source stream, measuring the source concentration strength, and estimating the rate of emission. For organic vapors and gases, the chemical composition and concentration of the constituents should be determined by the method described in Section IV.3.1.

Most dust emissions will be associated with the addition of dry mud ingredients from bags to the drilling fluid through bulk solids hoppers. The chemical composition of the dust can be identified through information printed on the chemical bag and from additional information provided by material safety data sheets for each chemical. However, a precise composition analysis of dust samples is not necessary to establish the hazard potential (as a nuisance particulate) of dust inhalation.

The composition of the drilling fluid will be determined through an inspection of the mud engineer's log book that will show the amount of drilling fluid compounds added to the mud during drilling. As for dusts, a precise element analysis of mud composition is not necessary. It is more useful to determine composition through the record of the type and number of bags added to the drilling fluid.

IV.4.3 Area Sampling

Area sampling will determine the concentration of gases, vapors and dusts in the breathing zone of rig workers whose duties require them to perform activities close to emission sources. For gases and vapors, air samples of a 10-minute duration should be collected in inert bags at several locations where workers congregate. The contents of the inert bags should be analyzed as described in Section IV.3.1. If the strength of the emission source is likely to vary with time, it will be necessary to perform both source and area sampling for gases and vapors simultaneously. These sampling activities should be repeated as necessary to properly characterize hazard potential.

Area sampling for dust should be performed as described in Section IV.3.2. The sampling pump and cartridge assemblies can be placed at different locations within the work areas in the vicinity of dust emission sources as necessary.

Chemical mists were seldom encountered during the SwRI observations on offshore drilling rigs. Area sampling activities for mists do not appear to be justified during subsequent observations. However, monitoring personnel should be alert for mist generation if it should occur.

IV.4.4 Dermal (Skin) Contact with Liquids

Previous observations reported in Section III have shown that dermal (skin) contact with drilling fluids and other potentially hazardous liquids does not occur intentionally. On the contrary, rig workers usually contact drilling fluids inadvertently, when it cannot be avoided. Therefore, subsequent observations of activities on the drilling floor and in the mud mixing area for one or more 12-hour shifts should be undertaken to document the likely occasions when a roughneck is splashed or accidentally comes into contact with drilling fluids or other potentially hazardous liquids.

IV.4.5 Documentation of Work Activities and Personal Sampling

The previous observations indicate that drilling rig workers in two job categories have the greatest potential for exposure to gases, vapors and dusts. These are:

- (1) the roughneck who routinely samples the drilling fluid at the shale shaker and measures the mud weight and viscosity of drilling fluid leaving the hole. This worker has the highest potential for exposure

to gases released from the drilling fluid during drilling operation, and,

- (2) the worker who routinely adds bags of dry drilling fluid ingredients through the bulk solids hopper. This worker has the highest potential for exposure to dusts during drilling operations.

Therefore, these two workers should be observed for one or more 12-hour shifts and their activities that bring them into contact with gases, vapors and dust should be documented. Personal sampling to determine their actual exposure should also be performed during the period of observation as deemed appropriate.

IV.4.6 Interpretation of Results

The source, area and personal sampling activities will provide a clearer understanding of the potential for exposure of offshore drilling rig workers to gases, vapors and dusts. However, it is noted that as drilling activities are variable from day to day, the emission of gases, vapors and dusts into the work areas is likely to vary as well. The interpretation of the gas, vapor and dust exposure data should proceed along the following lines:

- o Exposure sampling should be performed frequently to permit an estimation of the time dependent concentration $C(t)$ for each 12-hour shift.
- o A time-weighted average concentration may be estimated as

$$\bar{C}_{TWA} = \int_0^{12 \text{ hrs}} \frac{C(t) dt}{12 \text{ hrs}} = \frac{\sum C_i t_i}{\sum t_i}$$

for each 12-hour shift that is observed.

- o Current gas, vapor and dust exposure standards are based upon a continuous 8-hour workday and a 40-hour work week. The offshore work schedule does not conform to this definition.
- o The concentration exposure data may be interpreted in light of OSHA Compliance Criteria (OSHA Industrial Hygiene Field Operation Manual CPL2-2.20).
- o If allowed, (refer to Chapter II of the OSHA IHFOM) the permissible exposure limit (PEL) for the 12-hour extended work schedule should be adjusted.

o Compare \bar{C}_{TWA} with PEL for the extended work schedule by

- Calculating

$$Y = \frac{\bar{C}_{TWA}}{PEL}$$

- Identify the sampling and analysis error (SAE) for the chemical of interest from Chapter IX of the OSHA IHFOM.
- Calculating the upper and lower confidence limits (UCL and LCL) on the measured \bar{C}_{TWA} and

$$\begin{Bmatrix} UCL \\ LCL \end{Bmatrix} = Y \begin{Bmatrix} + \\ - \end{Bmatrix} \left(\frac{SAE}{PEL} \right) \sqrt{\frac{\sum C_i^2 t_i^2}{\sum t_i}}$$

- Assess compliance as follows:

if $LCL \geq 1$, non-compliance
if $LCL \leq 1$ and $UCL \geq 1$, possible overexposure
if $UCL \leq 1$, compliance

V. IMPLEMENTATION OF EXPERIMENTAL PLAN

A trial implementation of the experimental plan was conducted for both offshore drilling and production activities. The experiments were conducted on four platforms, designated as A, C, D, and F, in a field of five platforms located in the Gulf of Mexico. The platform arrangement and a list of facilities located on each platform are shown in Figure V.1. The activities of the observation team are summarized in outline form below.

o First Day

- Arrive at platform F with drilling rig and crew accommodation facilities.
- Inspect platforms F, D, and C with a representative of the operating company.
- Discuss the objective of this project and the purpose of our visit with crew members. Discuss and record their observations and experience regarding workplace exposure to hazardous materials.
- Gather information on crew size, duties and hours of work.

o Second Day

- Perform an area walk-through survey of all operation areas and living/office accommodations on platforms F, D, and C. The Organic Vapor Analyzer is used in the total hydrocarbon mode to locate contaminant emission sources.
- Identify contaminant emission sources, measure and document concentration level.
- Review the findings with the operating company representative.

o Third Day

- Obtain contaminant emission source samples from two flowing wells, a flotation cell (used to separate oil residue from produced water), and the gas compressor on platform C.
- Perform a gas chromatograph analysis on diluted samples of gas from the contaminant emission sources.

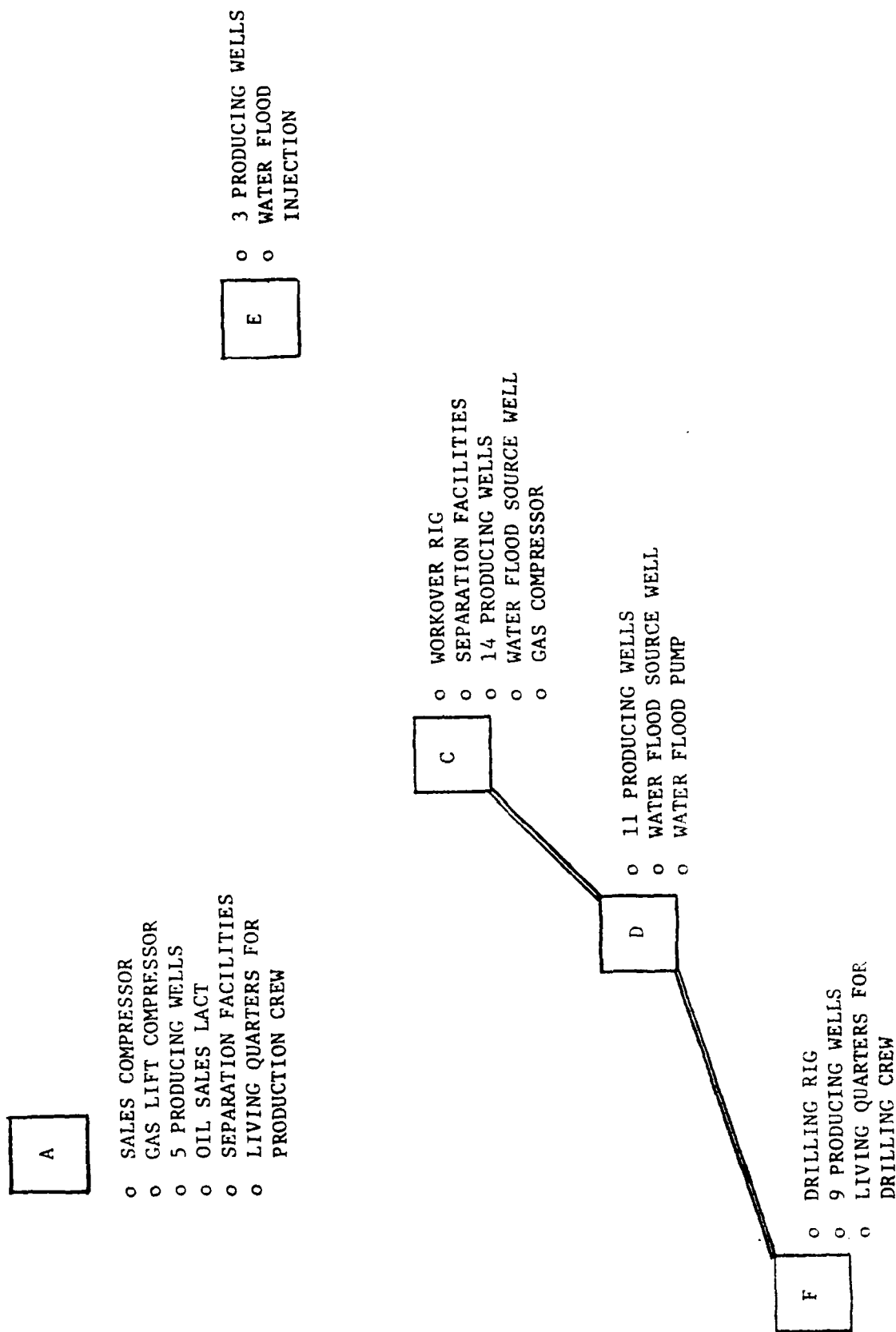


FIGURE V.1 ARRANGEMENT OF OFFSHORE PLATFORMS - TASK IV

o Fourth Day

- Obtain and analyze additional source samples of the demulsifier, flotation agent, and methanol additives used to treat process streams, and a sample of gas from the gas production line on platform C.
- Obtain and analyze area samples of air to determine gas concentration in the compressor room on platform C.
- Perform personal sampling for dust exposure on the mudman for a 12-hour shift on the drilling rig on platform F. Observe and record the activities of the mudman that involve exposure to dust and drilling fluids.

o Fifth Day

- Perform a walk-through area survey on platform A to locate contaminant emission sources using the Organic Vapor Analyzer. Identify and document emission sources and measure concentration levels.
- Obtain and analyze area samples of air for gas concentration near the flotation cell on platform C.

o Sixth Day

- Observe and record the activities of the mudman on the platform F drilling rig for a 12-hour shift. Perform personal sampling for dust exposure.
- Observe and record the activities of the driller, derrickman, and roughnecks on the drilling floor. Note any dermal exposure to drilling fluids.

o Seventh Day

- Review the preliminary results of our observations with the representative of the operating company.
- Return to shore.

The results of the contaminant sampling measurements are reported in Sections V.1 and V.2. The full trip report is included in Appendix L.

V.1 Production Platform

Table V.1 gives the job titles and work schedules for the lease production crew. Most of these people work 12-hour shifts for seven days followed by seven days off the job. Routine maintenance and most production operations are performed during day work. However, on platforms where drilling is taking place, a nightman is present to shut-in the wells if required in an emergency.

TABLE V.1. CREW COMPLEMENT FOR LEASE PRODUCTION WORKERS

PRODUCTION CREW (Platforms A, C and D)	Work Schedules		Number Per Shift		Notes
	7 days on/ 7 days off	5 days on/ 2 days off	Day	Night	
o Lease Operator	✓		1		Available on call
o Helper C & D	✓		1		Available on call
o Helper A	✓		1		Available on call
o Mechanic	✓		1		
o Mechanics		✓	2		
o Automatic Control Man	✓		1		
o Automatic Control Man		✓	1		
o Electrician	✓		1		
o Meterman		✓	1		
o Roustabouts		✓	3		
o Roustabouts	✓		2		
o Painters (contract)	✓		2		When required
o Operator assistant/ nightman	✓		1	1	Always on a platform during drilling for emergency well shut-in

In general, these workers do not spend all of their time in any one area. The mechanics, the electrician, the automatic control men and the metermen perform their duties, whether routine calibration, test, preventive maintenance or emergency repair, wherever it is needed. The roustabouts assist in installation and repair and perform boat loading/unloading and housekeeping tasks as required. The lease operator and helper perform necessary record keeping and administration tasks, and oversee the operation of the production equipment. On the other hand, the contaminant emission sources are fixed in location and number. It would be unusual to find a lease production worker whose job required him to be in the vicinity of a contaminant emission source at all times.

The walk-through surveys identified a number of sources of gaseous contaminant emissions on the production platforms. Several of these were fugitive emissions from leaking valves and flanges on well heads, and leaking connections on gas metering lines. The source area and the emission rate for fugitive type emissions are small, and the emitted gas cloud is rapidly diluted by the wind in outdoors locations to concentrations less than 100 ppm at a few meters from the source. However, fugitive emissions can be quite important when they occur in an enclosed space, such as an instrument cabinet or a room. In this case, the gas concentration in the enclosure may increase to a high equilibrium level that is determined by flow of ventilation air into and out of the enclosure and the fugitive emission rate.

The most important emission sources encountered during the walk-through survey were the following:

- o Gas emissions from the fuel (natural) gas engine and the oil transfer pump on platform A.
- o Gas emissions from the 1000 psi fuel gas compressor on platform C.
- o Gas and vapor emissions from the flotation cell on platform C.

Each of these emission sources produced a gas or vapor cloud with concentrations that exceeded 1000 ppm (total hydrocarbon concentration as methane) over a distance of several meters from the source.

Figure V.2 shows the results of total hydrocarbon concentration measurements during the walk-through survey near the oil transfer pump and gas engine on platform A. A gas cloud with concentrations exceeding 1000 ppm surrounded the fuel gas engine. The gas cloud extended into the engine generator room as shown in Figure V.2. With the aid of a diluter to mix ambient air into the sampled gas stream, the apparent emission source was found to be located at (or very near) a leaking water coolant line at the front of the gas engine. This is an unusual location for a source of fuel gas emission, and may be the result of a damaged engine block.

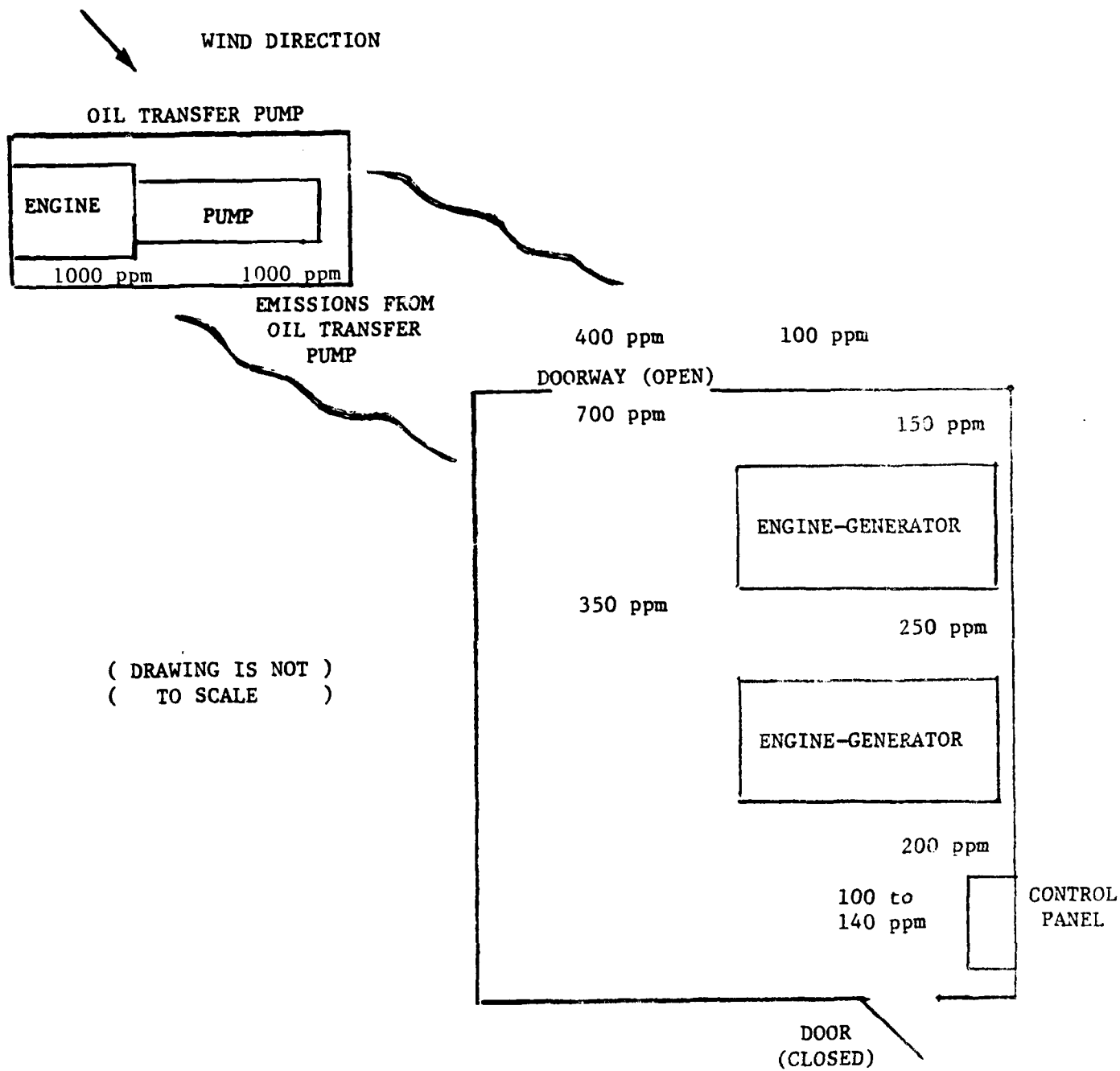


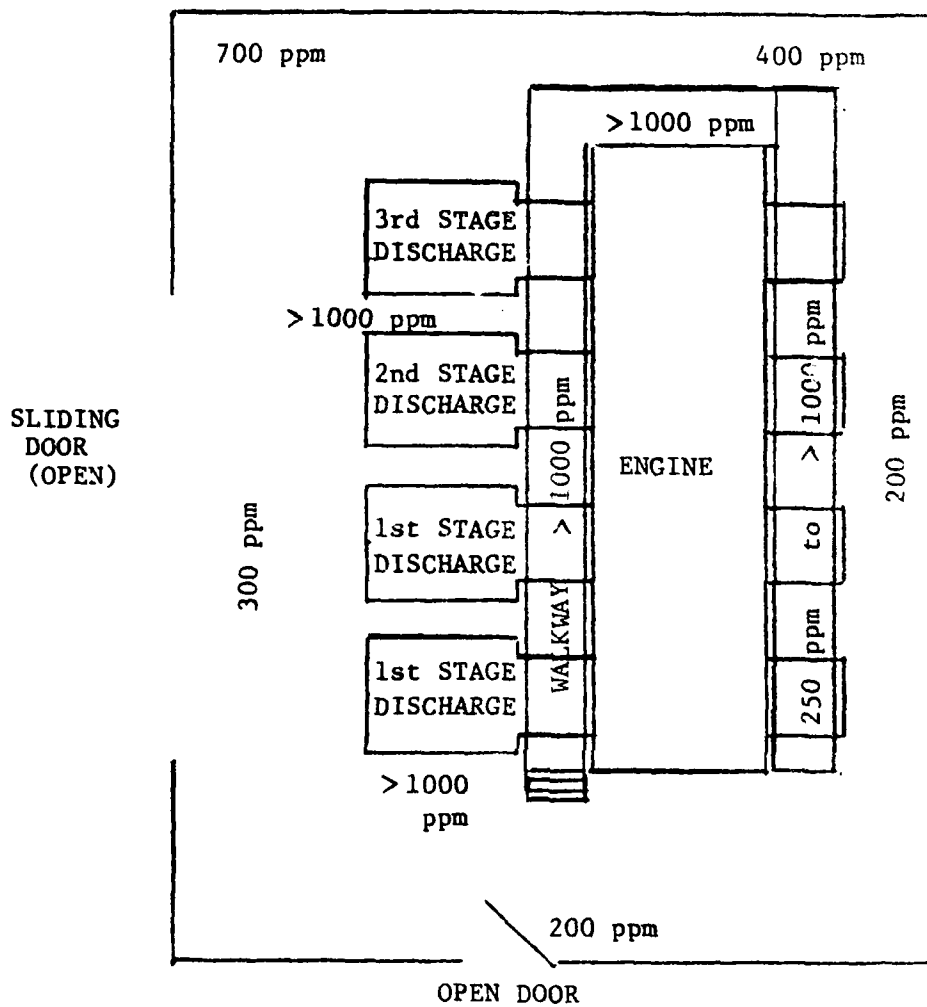
FIGURE V.2. VARIATION OF TOTAL HYDROCARBON CONCENTRATION NEAR THE OIL TRANSFER PUMP AND GENERATOR ROOM ON PLATFORM A

Figure V.3 shows the results of total hydrocarbon concentration measurements made during the survey of the 1000 psi fuel gas compressor room on platform C. Fugitive emissions were found at inspection panels on the 1st, 2nd, and 3rd stage compression discharge heads. Figure V.4 shows a source concentration gas sample being taken near a leak at the 2nd stage discharge head. High concentrations exceeding 1000 ppm were found near the discharge head and along the walkway above the compressor and gas engine. The compressor room was ventilated by natural circulation of air through open doors and windows. The gas concentration in the room ranged from 200 ppm to 700 ppm at locations away from the compressor itself.

The emissions from the flotation cell on platform C could easily be detected by smell, although the odor was not specially unpleasant. The flotation cell uses a combination of fuel gas, a demulsifier chemical, and a flotation agent to assist in the removal of dispersed oil droplets from produced water before the water is discharged into the sea. The rate of emission from the flotation cell on platform C was unusually high on this occasion because the gasket beneath one of the inspection panels was damaged. This formed a leakage path approximately 5 cm in length by about 2mm high through which the fuel gas "blanket" and vapors from the wet oil were free to escape. A similar flotation cell was operating normally on platform A. Our area surveys with the OVA did not indicate significant leakage of blanket gas from that unit.

Samples of the emissions from the fuel gas engine on platform A, the fuel gas compressor on platform C, and the flotation cell were analyzed by gas chromatograph. Table V.2 shows the results for the concentration analysis of hydrocarbon gases and vapors in a source sample obtained in the fuel gas compressor room. The source sample did not consist entirely of fuel gas. Some air from the compressor room was inevitably drawn into the sample bag along with the fuel gas. Assuming that the fuel gas is composed solely of the gases and vapors reported in Table V.2, then the percentage concentration distribution shown in Table V.2 can be calculated. This method of analysis indicates that the fuel gas contains more than 87% methane and lesser amounts of ethane, propane, butane, and pentane. Dry natural gas, with condensibles removed, usually has a methane concentration in the range of 85 to 95%.

Table V.3 shows the results for the concentration analysis of hydrocarbon gases and vapors obtained from the source sample taken at the flotation cell. In this case, hydrocarbons appear to comprise about 150,000 ppm (about 15%) in the sample with air and water vapor also present in the source sample bag. However, if we neglect the air and water vapor in the vapor blanket above the oil/water surface, the percentage distribution of hydrocarbons shown in Table V.3 can be calculated for the flotation cell emissions. Since fuel gas is bubbled into the water in the flotation cell, it is not surprising that methane accounts for 75% of the hydrocarbon concentration in the flotation cell emissions. We should note the increased concentrations of higher hydrocarbons (ethane through hexane) in these emissions compared with the fuel gas analysis in Table V.2.



(DRAWING IS NOT
(TO SCALE)

FIGURE V.3. VARIATION OF TOTAL HYDROCARBON CONCENTRATION
WITHIN 1000 psi COMPRESSOR ROOM ON PLATFORM C



FIGURE V.4. SOURCE SAMPLING AT A FUGITIVE EMISSION SOURCE ON THE 2ND STAGE
DISCHARGE HEAD OF THE FUEL GAS COMPRESSOR, PLATFORM C

TABLE V.2. RESULTS OF SOURCE SAMPLING IN COMPRESSOR ROOM

	C ₁ methane ppm	C ₂ ethane ppm	C ₃ propane ppm	i C ₄ i-butane ppm	C ₄ n-butane ppm	i C ₅ i-pentane ppm	C ₅ n-pentane ppm	i C ₆ i-hexane ppm	C ₆ n-hexane ppm
Analysis of Source Sample	77,500	4,800	3,000	1,700	800	530	410	*	*
Percent Distribution of Hydrocarbons	87.3%	5.4%	3.4%	1.9%	0.9%	0.6%	0.5%	< 0.1%	< 0.1%

NOTE: * - Peak area too small to resolve accurately.

TABLE V.3. RESULTS OF SOURCE SAMPLING AT THE FLOTATION CELL

	C ₁	C ₂	C ₃	i C ₄	C ₄	i C ₅	C ₅	i C ₆	C ₆
	methane ppm	ethane ppm	propane ppm	i-butane ppm	n-butane ppm	i-pentane ppm	n-pentane ppm	i-hexane ppm	n-hexane ppm
Analysis of Source Sample	108,000	14,800	7,870	3,450	3,690	1,870	2,340	1,360	1,360
Percent Distribution of Hydrocarbons	74.6%	10.2%	5.4%	2.4%	2.5%	1.3%	1.6%	0.9%	0.9%

Area samples of 10-minute duration were taken in the fuel gas compressor room and downwind of the flotation cell to determine the concentration of gases and vapors in the breathing zone at typical work locations. Figure V.5 shows the total hydrocarbon concentrations measured at three sampling locations downwind of the flotation cell. The highest concentration, greater than 1000 ppm as methane, was measured at station 14 closest to the flotation cell. The concentration distribution determined from gas chromatograph analysis for stations 14, 15, and 19 is shown in Table V.4. Concentrations of methane, ethane, propane, and iso-butane have been estimated by assuming proportionality between the source gas concentration distribution in Table V.3 and the area sample concentration distributions.

The concentration values in Table V.4 may be compared with recognized safe concentration limit values for flammability and toxicity. Methane, ethane, and propane gases are classed as simple asphyxiants. These gases are safe to breathe so long as they do not displace too much air and oxygen from the breathing zone. A concentration of up to 21% of methane, ethane and propane in combination would reduce the oxygen content to about 16-1/2%, which is the lower limit for safe work conditions. However, hydrocarbon concentrations of this magnitude are normally not permitted on offshore platforms. Combustible gas detection equipment is used to protect enclosed areas such as compressor rooms, engine generator and turbine generator rooms, offices, and electrician's and mechanic's workplaces. These systems detect the presence of combustible gases in the air and sound an audible alarm at 1% by volume and shut-in the platform at 3% by volume (as methane). Since the estimated concentration levels of methane, ethane and propane in Table V.4 are well below 1% (10,000 ppm), the exposure to these gases does not constitute a hazard.

The maximum acceptable workplace concentrations recommended by ACGIH for butane, pentane and hexane are given by the TWA-TLV values listed in Appendix J. These are:

o Butane (normal butane)	800 ppm
o Pentane (normal pentane)	600 ppm
o Hexane (normal hexane)	50 ppm
(other isomers)	500 ppm

The measured (and estimated) concentration levels of butane, pentane and hexane shown in Table V.4 are also below these maximum permissible levels. The analysis of area sampling data from the fuel gas compressor room gave the same result. Therefore, it can be concluded that the level of exposure of workers to hydrocarbon gases and vapors that is likely to occur on offshore production platforms does not constitute a health hazard by present standards if these results are representative of the industry.

TABLE V.4. RESULTS OF AREA SAMPLING DOWNWIND OF THE FLOTATION CELL

Sample Number	Total Hydrocarbon Concentration ppm	C ₁ methane ppm	C ₂ ethane ppm	C ₃ propane ppm	i C ₄ i-butane ppm	C ₄ n-butane ppm	i C ₅ i-pentane ppm	C ₅ n-pentane ppm	i C ₆ i-hexane ppm	C ₆ n-hexane ppm
14	1000 Offscale	* (1200)	* (160)	* (87)	* (38)	15.5 (41)	26.7 (21)	21.6 (26)	16.0 --	14.1 --
15	650	* (220)	* (30)	* (16)	* (7.1)	5.6 (7.6)	4.7 (3.9)	3.4 (4.8)	2.9 --	2.7 --
19	320	* (170)	* (23)	* (12)	* (5)	2.6 (5.8)	2.3 (2.9)	2.9 (3.7)	2.3 --	2.0 --

NOTES: Values in parentheses are estimated from the ratio of hexane to C₁ through C₅ in the Source Sample, Table L.13.

* - Peak area was too small to resolve accurately.

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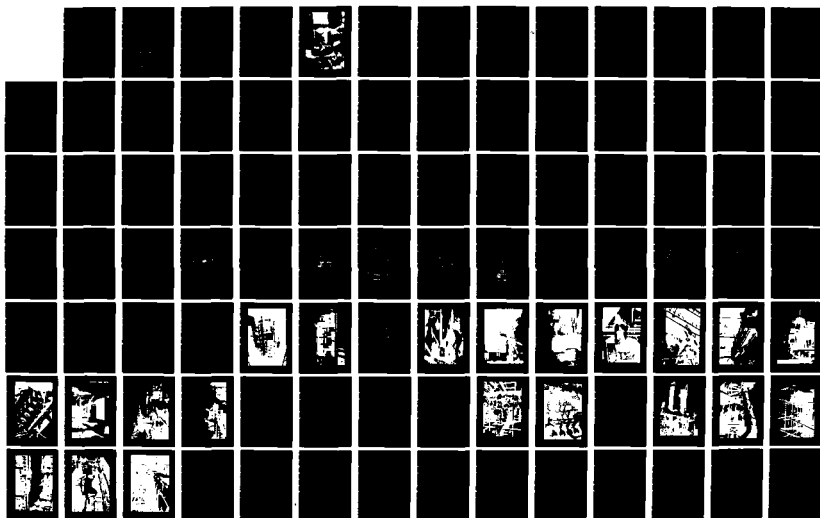
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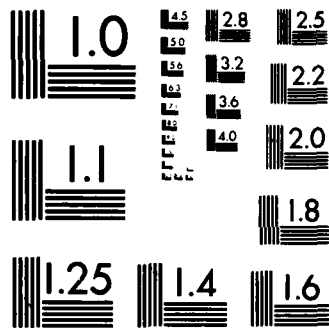
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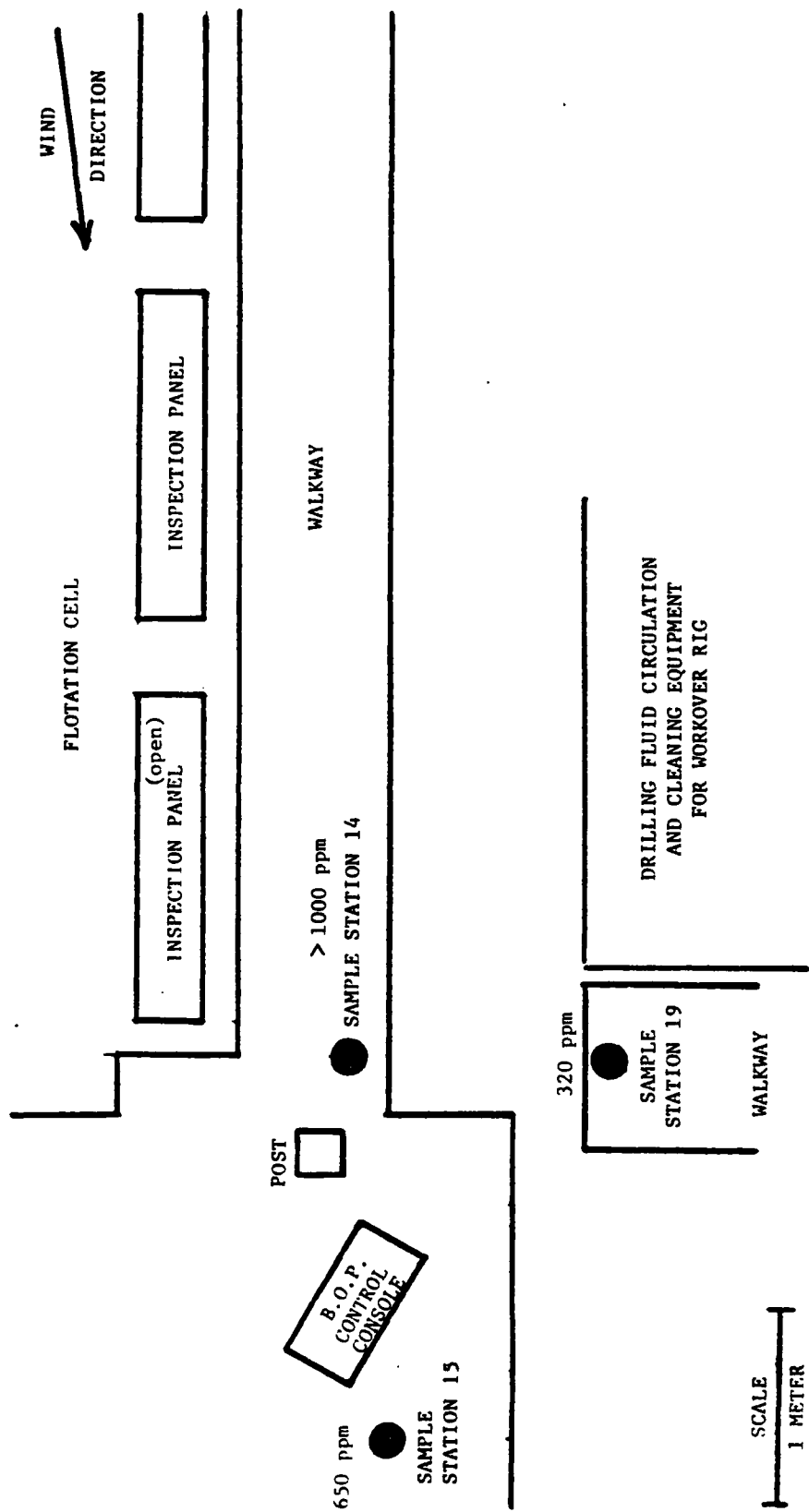


FIGURE V.5 ARRANGEMENT OF AREA SAMPLING STATIONS DOWNWIND OF FLOTATION CELL

During this observation on offshore production platforms, no liquid mists or dust clouds associated with production operations were found. Sandblasting and repainting of platform facilities were observed, but they did not appear to jeopardize the health and safety of workers. In particular, the area in which sandblasting took place was curtained off from the rest of the platform by clear plastic sheeting.

Potentially hazardous liquids such as bactericides are used in offshore production operations. No incidents of skin contact with these liquids was observed. The operating company has developed safe practice rules for the handling and storage of these liquids. These rules must be observed during all production operations.

V.2 Drilling Rig

Table I.5 reports the job titles and work schedules for the crews on the workover rig on platform C and on the drilling rig on platform F. All crewmen work 12-hour shifts for seven days followed by seven days off the job. Since drilling is carried out 24 hours around the clock, two drilling crews consisting of a driller, derrickman and three roughnecks work alternate 12-hour shifts. The toolpusher and directional driller routinely work the twelve-hour day shift, but are also available on call when needed outside normal hours. Routine maintenance services are usually performed during the day shift. When necessary, the mechanic/electrician works overtime.

Of all the drilling crewmen, the roughneck/mudman has the greatest potential for exposure to production gases, dry chemical dust, liquid chemicals, and the drilling fluid. The mudman takes cutting samples and drilling fluid samples at the shale shaker where natural gas from hydrocarbon bearing formations may be released from "gas-cut" mud. On this particular rig, the mudman was also responsible for adding dry drilling fluid materials to the mudpit through the dry bulk hoppers, as shown in Figure V.6.

During each 12-hour shift, the mudman performs several activities.

- o Measurement of the weight and viscosity of the mud to and from the hole every 30 minutes.
- o Collection of cuttings from the shale shaker every 30 feet of drilled hole.
- o Measurement of a complete set of drilling mud properties once every shift.
- o Addition of barite to the mud to maintain the mud weight specified by the mud program.
- o Addition of liquid chemicals (aluminum stearate and a defoamer) to the mud.

TABLE V.5 CREW COMPLEMENT - DRILLING CREWS

WORKOVER RIG (PLATFORM C)	Work Schedules		Number Per Shift		Notes
	7 days on 7 days off	5 days on 2 days off	Day	Night	
• Driller	✓		1	1	
• Derrickman	✓		1	1	
• Rotary Helpers	✓		2	2	
• Roustabouts	✓		3	2	
• Crane Operator	✓		1	1	
• Mechanic/Electrician	✓		1		Subject to overtime
• Fishing Tool Man	✓		1		Available on call
DRILLING RIG (PLATFORM F)					
• Drilling Foreman (Toolpusher)	✓		1		Available on call
• Clerk	✓		1		
• Driller	✓		1	1	
• Derrickman	✓		1	1	
• Roughnecks - Rotary Helpers	✓		2	2	
• Roughneck - Mudman	✓		1	1	
• Roughneck - Trainee	✓		1	1	
• Motor man	✓		1	1	
• Mechanic/Electrician	✓		1		Subject to overtime
• Crane Operator	✓		1	1	
• Welder	✓		1		
• Roustabouts	✓		1	1	
• Roustabouts (contract)	✓		4	4	
• Cementer (contract)	✓		1		Available on call
• Directional Driller (contract)	✓		1		Available on call
• Mud Engineer	✓		1		Available on call
• Galley Staff (contract)	✓		3	2	
• Quarters personnel	✓		1		



FIGURE V.6. PERSONAL SAMPLING FOR DUST EXPOSURE DURING CHEMICAL ADDITION TO DRILLING FLUID

- o Addition of dry chemicals to the mud from sacks

- ferro-chrome lignosulfonate
- lignitic material
- fluid loss additive
- caustic soda
- bentonite
- ground nut shells

A major treatment of 85 to 90 sacks over two to three hours was performed about once every 12 hours.

- o Washing the shale shaker and the slugging pit.

- o Helping on the drill floor during pipe changes.

To determine whether contact with gases, vapors, dusts and liquids constituted a hazard, observations of drilling activities and measurements of gas and dust concentrations were performed. A walk-through area survey for hydrocarbon gases and vapors found no emission sources on the drilling rig except for a small release of gas from the mud at the shale shaker. The mud was not appreciably gas-cut on the two occasions when vapor concentrations were measured at the shale shaker. The gas concentration at the mudman's usual work stations was negligible. Above the shale shaker screens and the mud surface, the gas concentration ranged from about 40 ppm to 150 ppm. The shale shaker has a gas detector fitted to it that sounds an alarm on the drilling floor if the mud gas concentration approaches flammable levels.

Visual observations of activities in the mud makeup room indicated that a noticeable amount of dust was released when a drilling fluid treatment was prepared. The mudman wore a particle dust mask, but did not wear gloves during chemical addition as shown in Figure V.6. To determine the concentration of respirable dust in the mudman's breathing zone, dust sampling samples of 100-minute duration were collected for the mudman and an observer standing nearby. The results are shown in Table V.6. A cyclone sampler was used for these tests so that the concentrations measured are for respirable dust particles. All of the dust concentration shown in Table V.6 are below the upper permissible limit of 5 mg/m³ for nuisance dust.

It was noted that most of the airborne dust was generated by the ferrochrome lignosulfonate and the lignitic material. The caustic soda was in the form of beads and did not produce visible dust. Also, the ground nutshells were coarse in texture and generated little or no dust. Although the measured levels of respirable dust were below the allowable maximum, the wearing of a dust particle mask by the mudman should continue to be encouraged since it prevents accumulations of larger non-respirable particles in the nose and mouth.

TABLE V.6 RESULTS F DUST CONCENTRATION MEASUREMENTS FOR THE MUDDMAN

Sampling Period	Respirable Dust Concentration mg/m ³	Activities
1	2.12	Added barite from bulk tank and 78 bags of chemicals over 51 minutes
2	0.25	Added barite and 18 bags of chemicals over 22 minutes
3	0.00	Added barite and 11 bags of chemicals over 12 minutes
4	0.65	Added barite and 2 bags of chemicals over 21 minutes
5	0.70	Added barite and 2 bags of chemicals over 28 minutes
6	1.04	Added barite and 11 bags of chemicals over 43 minutes

Visual observation also indicated that the mudman was not subjected to prolonged contact with either the drilling fluid or chemical added to the mud in liquid form. Dermal contact with these liquids was usually accidental, and the mudman washed his hands and arms under running water in the mud lab after each exposure.

Observations of activities on the drill floor were conducted to look for dermal contact with the drilling fluid. Spillage of mud onto the drill floor was observed on one occasion. One roughneck was splashed with mud when breaking the connection between the kelly and the last length of drill pipe. He completed his assistance in adding a new length of pipe to the drill string, then left the drill floor to wash away the mud in the changing room. His body surface area in contact with mud was very small, and the duration of contact was less than 10 minutes. The roughneck experienced no adverse effects from this contact.

VI. OFFSHORE NOISE STUDIES

VI.1 Object of the Study

As a result of the efforts of the U.S. Coast Guard to insure the health of personnel working in the offshore industry, a study was initiated to assess the impact of noise on employee hearing. While the Occupational Safety and Health Act, OSHA, was designed to provide a guideline for the protection of hearing for industrial workers, the offshore environment contains several unique factors which limit direct application of OSHA guidelines. Specifically, offshore personnel work 12-hour shifts with the added variable of working shifts of 7 days on/7 days off. While many researchers agree that the seven-day-off recovery period will be beneficial, no one has posed a mutually agreeable method for determining either the permanent threshold shift, PTS, due to exposure to intermittent, variable sound or the correlation of temporary threshold shift (TTS) with PTS.

The specific objectives of this study as defined by the U.S. Coast Guard (USCG) were to:

1. Perform a literature survey to assess the availability of noise exposure data and noise reduction approaches applicable to the offshore industry.
2. Develop a plan for the collection of the data which could be used by USCG to develop a practical hearing protection guideline. The actual testing will be conducted at a later date.

VI.2 Survey of the Literature

VI.2.1 Open Technical Literature

Prior to developing a test plan, a search of the open technical literature aimed at finding specific information on offshore noise exposure and applicable standards was conducted. Because of the similarity between land based equipment and equipment found on offshore facilities, no effort was made to collect noise abatement techniques except where the literature specifically treated noise reduction with examples on offshore structures. The computerized literature search employed two library information systems available at SwRI. The data bases reviewed included "NTIS," covering government reports of 240 agencies, and "Compendex," which corresponds to the Engineering Index Monthly.

The following descriptors were input into "Compendex":

<u>SET</u>	<u>DESCRIPTOR</u>	<u>NO. OF ITEMS LOCATED</u>
1	Acoustic?	18645
2	Noise	25568
3	Sound	10421
4	Standard?	33178
5	Measure?	161687
6	Abatement	4518
7	Control?	138489
8	Rating	2431
9	Offshore	5657
10	Drilling	7317
11	Production	47479
12	Petroleum	14750
13	Oil	29497
14	Gas	62854

In order to specifically isolate useful items only, these descriptors were combined as follows:

<u>SET</u>	<u>DESCRIPTOR</u>	<u>NO. OF ITEMS LOCATED</u>
15	1-3/OR	44704
16	4-5/OR	187808
17	4-8/OR	306684
18	10-11/OR	53492
19	12-14/OR	90702
20	15 and 16 and 18 and 19	57
21	15 and 16 and 9 and 19	21
22	15 and 16 and 9 and 18	18
23	15 and 17 and 18 and 19	110
24	23 NOT 20	53
25	20-23/OR	121

Abstracts for the 121 items located in Set 25 were reviewed and seven of these articles were ordered. The abstracts for these seven appear in Appendix M. The same descriptors were input in "NTIS," but no usable items were located.

In the process of selecting descriptors and reviewing the abstracts located in these searches, several factors were considered. First, reports and papers which were not directly concerned with the offshore industry were eliminated. It was recognized that while it might be possible to locate sound level data measured on land for specific pieces of equipment used both onshore and offshore, little of this case-specific data would be useful because of the special problems (such as tighter equipment spacing) associated with the offshore industry.

Second, the search was made open to all aspects of acoustic noise - sound levels, measurement techniques and industry or government standards and regulations. It was recognized that these general categories could conceivably yield a large number of irrelevant items. However, it was felt important not to restrict the search and thereby suppress the output of potentially useful data.

Five of the seven items ordered have been received. Each of the items was reviewed and a brief statement reflecting the applicability of the item to this study was prepared. The following is a summary of the reviews for the five items.

1. "Designing to Meet Specific Noise and Vibration Criteria on Offshore Platforms"

The authors classify the platform into three physical regions:

- o work areas,
- o control rooms, and
- o accommodation areas.

Corresponding allowable noise levels were set at 90 dBA in the work areas, 60 dBA in the control rooms, and 45 dBA in the accommodation areas. These levels were established to provide an acceptable environment for various tasks. For example, if communication is required, the noise level must be low enough to ensure intelligible communications. The accommodation area standard was based on the effect of noise on sleep. However, this paper does little more than restate material available throughout the literature. It does not provide specific data useful for this study.

2. "Noise Exposure and Control on Fixed Marine Structures"

The author lists several "typical design limits" for noise exposure on offshore structures which have been adjusted to compensate for the difference in exposure time" between onshore and offshore operations. These limits are:

o Emergency Sources	115 dBA
o Machinery Rooms	85 dBA
o Workshops and Laboratories	80 dBA
o General Work Areas	75 dBA
o Control Rooms	55 dBA
o Offices and Radio Rooms	55 dBA
o Kitchen and Laundries	60 dBA
o Dining and Recreation Rooms	55 dBA
o Sick Bays and Dispensaries	50 dBA
o Libraries and Music Rooms	50 dBA
o Sleeping Quarters	45 dBA

However, these "design limits" are not maximum values based on comprehensive noise measurements and/or medical hearing loss evaluations. Consequently, they are not accepted by industry as either necessary to prevent hearing loss or practical to implement. The author's own listing of measured noise levels for various platforms indicates that his "design limits" are generally exceeded. Therefore, all aspects of establishing noise limits (see Sections VI.4 and VI.5) should be addressed before realistic limits are finalized.

3. "Noise Control Engineering Experience with Offshore Oil and Gas Platforms and Related Refinery and Process Equipment"

This paper contains a listing of a few "typical" noise levels encountered on offshore structures. It also discusses several procedures for reducing noise levels. In general, there is little that can be applied to this study.

4. "Offshore Drilling and Production Noise Level & Acoustic Communications Reliability - Field Data"

This paper deals with sub-surface noise which may interfere with an acoustic command system being used for acoustic buoy release, valve control, subsea production control, blowout preventer control, etc. There is no information directly suited to this study.

5. "Solving Flare - Noise Problems"

This paper is concerned solely with flare noise - abatement techniques and equipment. This can be a significant problem on production platforms and could be useful.

Between "Compendex" and "NTIS", a data base of more than one million items was searched to find the papers selected. It was concluded that the type of exposure data required by USCG is virtually nonexistent in the open literature. Standards related to 7 days on - 7 days off in which workers are on the job 12 hours per day could not be found. Noise abatement techniques which consider the specific problems encountered on offshore structures (i.e., close quarters, relatively light structures, high level of moisture, salt environment, etc.) are extremely limited. In addition, there are virtually no data correlating noise levels and duration of worker exposure.

VI.2.2 Unpublished Noise Data

In addition to the review of the open technical literature, unpublished data were reviewed from both SwRI and industry sources. This information, an example of which is presented in Figure VI.1, will be used to augment the data collected in the experimental phase to be conducted later.

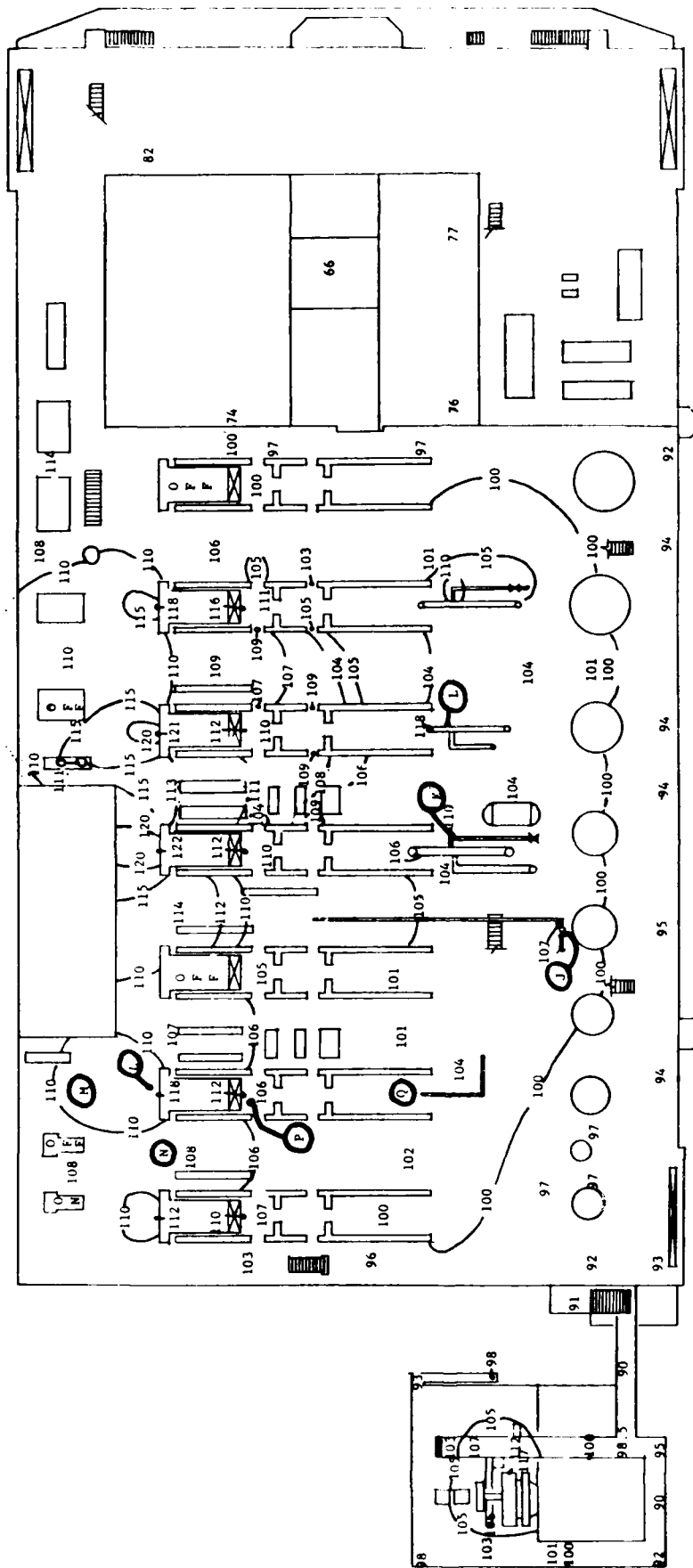


FIGURE VI-1. EXAMPLE OF SOUND LEVEL CONTOURS IN dBA AT AN OFFSHORE FACILITY
(Circled Letters Indicate Octave Band Test Point Locations)

VI.3 Discussion of Available Materials

VI.3.1 Hearing Loss

To date, medical research has been unable to develop an adequate model for ear response to intermittent, variable noise exposures. One of the major problems of establishing such a model is the large variation between individuals in their susceptibility to hearing damage.* A second problem which precludes the use of hearing loss to set noise level criteria is the lack of existing data. As the discussion and abstracts of Section VI.2.1 illustrate, there is virtually no published data which addresses the unique exposure factors typical of the offshore industry.

Considering these factors, SwRI has determined that measurements of hearing loss (i.e., audiometric testing) would not provide useful data for developing noise level guidelines. However, the use of audiometric testing as a means of validating proposed guidelines is possible. Specifically, a validation test plan could be developed to include audiometric tests of offshore workers. Such a plan would require a relatively large number of workers to receive audiometric tests at the start of a 7-day work shift and again at completion of their shift. The testing should be conducted over a period of time (one or more years) which would permit the development of a valid statistical data base. An obvious limitation in this type of testing is the failure to account for noise exposure during the 7-day recovery period.

VI.3.2 Noise Reduction

Unlike the lack of information for defining or predicting the mechanism of hearing loss, a large amount of technical data exists on noise reduction techniques. Research has been conducted on the general problem of damping structure-borne noise, reducing vibration amplitudes, and acoustically isolating facilities. In addition, there is a large amount of excellent data on specific practical problems which have been encountered in other industries. Many of these same procedures which have been utilized in land-based gas pipelines, and chemical and petrochemical plants could also be applied to offshore installations. In general, potential noise abatement is not limited by technology. Rather, it is limited by the cost of implementing the technology, particularly in retrofits.

* Robinson, D. W., "The Relationship Between Hearing Loss and Noise Exposure," NPL AERO Report Ac 31, July 1968, United Kingdom.

VI.3.3 Exposure Levels

An essential piece of data necessary for determining noise reduction requirements and compliance with guidelines is the noise dosage. Noise dosage (the time-weighted sound exposure pattern) can be determined using several procedures. One method involves placing a dosimeter on an individual to obtain a single overall or total dosage. The usefulness of this data can be enhanced by performing a parallel time-motion study to establish the specific noise sources that contributed to the dosage. Once a statistically valid number of data points have been obtained, the information can be used to establish work schedules which will ensure compliance with recommended guidelines and to identify areas which require noise reduction.

Another procedure for determining noise dosage is to determine isobars near typical sources and correlate the total time that a particular worker or class of worker typically spends within a given area with these pressure levels. The exposure duration can be estimated based on the worker's responsibilities or it can be determined by tracking his motion during a shift. This procedure has been used by SwRI, and an example of the type of data obtained is presented in Table VI.1. The data presented in Table VI.1 are based on measurements conducted by SwRI for a chemical firm.

The exposure fractions were determined by taking the ratio of the actual time the worker was exposed to the total time allowed at a given sound level. The allowed times are based on OSHA regulations of 90 dBA for 8 hours. Summing the individual exposure fractions yields a number which indicates what fraction of the total allowable exposure occurred. Therefore, any value greater than 1 indicates an exposure above the allowable limits.

VI.4 Description of the Problem

VI.4.1 Nature of the Problem

Available hearing protection criteria have been established for individuals exposed to noise for an 8-hour day and a 5-day work week. However, employees on offshore facilities are exposed to platform noise for a normal maximum of twelve hours per day (assuming quiet sleeping areas), and are scheduled for 7 days of working alternated with 7 days off. In addition, although several studies have documented statistical incidence of noise induced permanent threshold shift (NIPTS) in the general population (Reference Table VI.2), no data exist to define the magnitude or existence of NIPTS in the offshore population. As a result of these problems, several discussions were held with the USCG in order to orient the development of the experimental plan for noise measurement. This was necessary to ensure that the data collected would be of value in setting criteria levels.

TABLE VI.1
SAMPLE OPERATOR NOISE DOSAGE CALCULATION

EVALUATION OF PLANT NOISE USING DEPARTMENT
OF LABOR REGULATIONS*

Unit: Unit 7
Operator: C Utility

Duty	Area	SL Meas.	t _{act}	t _{allow}	Exposure Fraction
Burner Area Check	Walk to Area	91	1m	420m	0.002
	"	87	2m	---	0.000
	Area check in				
	Front B-1 & B-2	94	15m	280m	0.054
	"	92	15m	360m	0.042
	Burner Fan Lube	95	10m	240m	0.042
	"	105	5m	60m	0.083
SR-2/WH-1 Check	Near P-302	92	37m	360m	0.103
	"	94	20m	280m	0.071
	Area Movement	91	10m	420m	0.024
	Near SR-2	94	10m	280m	0.036
	Near WH-1	96	10m	210m	0.048
Cooling Tower Check	Walk to Area	85	1m	---	0.000
	"	92	1m	360m	0.003
	"	96	1m	210m	0.005
	Around CT-1	<85	27m	---	0.000
	Around P-100	90	15m	480m	0.031
	"	94	15m	280m	0.054
	On CT-1 Platform	86	15m	---	0.000
	Near S-121	<85	15m	---	0.000
River Water Pump Area	Walking to Area	<85	3m	---	0.000
	Pump Area	90**	27m	480m	0.056
Vicinity C-4	Walk to Area	92	1m	360m	0.003
	"	96	1m	210m	0.005
	C-4 Area	92	58m	360m	0.061
Patrol Round	C-20 Area	94	15m	280m	0.054
	E-31 to E-39	92	15m	360m	0.042
	E-39 to E-22	90	15m	480m	0.031
Control Room		62	120m	---	0.000
			480		0.950

* OSHA Exposure Fractions Calculated on a basis of 90 dBA for 8 hr. exposure.

** Assumed Level.

TABLE VI-2. RELATION BETWEEN RISK AND
EQUIVALENT CONTINUOUS SOUND *

Level for up to 45 Years of Habitual Exposure (Age = 20 Years + Years of Exposure) (% Noise = "Risk" as defined in document)													
(All data have been corrected to a median hearing level of 0 dB for 80 dBA exposure and 25 yrs. of age.)													
Age		20	25	30	35	40	45	50	55	60	65		
Exp. Years (Age - 20)		0	5	10	15	20	25	30	35	40	45		
Exp. Level	Total % Expected	0.7	1.0	1.3	2.0	3.1	4.9	7.7	13.5	24.0	40.0		
80 dBA	% Due to Noise	No Increase in Risk at This Level of Exposure											
Exp. Level	Total %	0.7	2.0	3.9	6.0	8.1	11.0	14.2	21.5	32.0	46.5		
85	% Noise	0.0	1.0	2.6	4.0	5.0	6.1	6.5	8.0	8.0	6.5		
Exp. Level	Total %	0.7	4.0	7.9	12.0	15.0	18.3	23.3	31.0	42.0	54.5		
90	% Noise	0.0	3.0	6.6	10.0	11.9	13.4	15.6	17.5	18.0	14.5		
Exp. Level	Total %	0.7	6.7	13.6	20.2	24.5	29.0	34.4	41.8	52.0	64.0		
95	% Noise	0.0	5.7	12.3	18.2	21.4	24.1	26.7	28.3	28.0	24.0		
Exp. Level	Total %	0.7	10.0	22.0	32.0	39.0	43.0	48.5	55.0	64.0	75.0		
100	% Noise	0.0	9.0	20.7	30.0	35.9	38.1	40.8	41.5	40.0	35.0		
Exp. Level	Total %	0.7	14.2	33.0	46.0	53.0	59.0	65.5	71.0	78.0	84.5		
105	% Noise	0.0	13.2	31.7	44.0	49.9	54.1	57.8	57.5	54.0	44.5		
Exp. Level	Total %	0.7	20.0	47.5	63.0	71.5	78.0	81.5	85.0	88.0	91.5		
110	% Noise	0.0	19.0	46.2	61.0	68.4	73.1	73.8	71.5	64.0	51.5		
Exp. Level	Total %	0.7	27.0	62.5	81.0	87.0	91.0	92.0	93.0	94.0	95.0		
115	% Noise	0.0	26.0	61.2	79.0	83.9	86.1	84.3	89.5	70.0	55.0		

* From "Third Draft Secretariat Proposal for Assessment of Noise Exposure During Work for Hearing Conservation Purposes, ISO/TC, 43/SC-1, "Noise".

Specifically, three types of data are necessary for establishing a hearing protection criterion. The three types are typical noise dosages, the hearing loss experienced, and correlations between the two. To determine these, four possible approaches could be explored.

VI.4.2 Possible Approaches

1. Hearing Loss Survey

One recommendation is that a survey of actual hearing loss be conducted. This survey would include studying existing company records of hearing damage and augmenting this information with additional audiometric tests necessary to complete the records. These data could then be compared to similar society norms as shown in Table VI.2, with a standard set similar to the OSHA approach, but implementing those specific adjustments found as a result of the data. This procedure would provide a more factual basis for an acceptable USCG standard; the main disadvantage would be that there is no easy way to eliminate non-job related exposure.

2. Survey and Temporary Threshold Shift Tests

A second approach would incorporate a Temporary Threshold Shift Test (TTS₂) with the Hearing Loss Survey. The TTS₂ measurements would be administered at the end of the last shift workday and before the start of a new work shift. The recovery mechanism for intermittent variable noise exposure could then be judged. One of the biggest unknowns in offshore noise exposure is the magnitude of this recovery mechanism. A standard based on these data could then be established. The major drawback to this approach is that it would require a significant test sampling, with non-job related exposure again contaminating the results.

3. Modification of Existing Standards

A third approach in setting criteria for hearing protection could use a simple equation drawn from existing standards and guides. Using the OSHA standards expanded for a 12-hour day, the allowable exposure to noise is approximately 87 dBA. If exposure were restricted to only one-half of a year, an equation could be computed using 5 dBA per halving time, which would set the base level for a 12-hour day at 92 (the OSHA standard of 87 plus 5 for halving the exposure time). In a simplified presentation, this would allow a noise level of 90 dBA for 12 hours for personnel who worked a schedule of 7 days on, 7 days off. This method could be both a simple and technically supportable solution.

4. OSHA Standard

Finally, the fourth approach could use the simple assumption of OSHA at 90 dBA per 8-hour days, and would provide USCG with a widely accepted standard. The disadvantages of this approach center on its being overly restrictive and costly for offshore facilities.

VI.4.3 Selection of Appropriate Approach

Because there is no firm basis for establishing any of these criteria, tentative guidelines should be implemented. Then after approximately one year of use, these guidelines could be reviewed together with a year's worth of noise data and practical experience to determine if they should be modified or permanently implemented.

Also, due to the experience of the National Institute of Occupational Safety and Health, NIOSH, in the development of noise criteria, USCG should enlist their assistance in the actual development of offshore noise guidelines.

With this approach, the collection of typical offshore noise dosage data is required. These data should include both sound pressure levels measured on offshore installations, and employee time exposure patterns. However, this information should not necessarily be presented in the same form as NOSC Technical Bulletin No. 405*. While the data presented in Section VI.2 does list typical exposure levels, it still lacks sufficient information to highlight problem areas, especially which equipment contributed to significant noise dosage. Establishing these exposure levels requires the actual detailed time and motion of the individual.

VI.5 Experimental Plan

VI.5.1 General Approach

The purpose of the experimental plan is to provide typical sound pressure levels and operator noise dosages as measured at a range of offshore facilities.

Offshore facilities can be broadly grouped into three categories based on their sound fields (i.e., amplitude, duty cycles and frequency):

- drilling platforms,
- production platforms with reciprocating compressors,
- production platforms with turbine driven compressors.

A fourth category, "Enclosed Platforms," typical of colder climates, could be tested; however, since their numbers are relatively small compared to the "open" platforms typical of the Gulf Coast, they have not been included in the test plan.

* Schmidt, D. R., "Noise Levels and Crew Noise Exposure Aboard U. S. Merchant Vessels," Technical Report NOSC 405, prepared by Naval Ocean Systems Center, 30 April 1979.

For each platform studied, a set of drawings showing typical sound levels with sound level contours would best define the noise environment and allow study of individual equipment contributions as well as related data of directivity, reflection and reverberation. Such a drawing is shown as Figure VI.1.

For each platform, a noise dosage presentation similar to that in Table VI.1 should be made for each class of operator. These dosage tables should include not only the 12-hour work day but also the 12-hour rest period. As with shipboard exposure to noise, it is necessary to obtain "typical" off duty noise dosages to determine if this rest period does in fact provide sound levels low enough to allow recovery of TTS accrued during the work periods.

VI.5.2 Raw Data

1. Sound Level Measurements

The collection of sound pressure level data on drilling rigs will require that several surveys be made during a 7-day shift. The normal operating procedure on a drilling rig is such that noise sources may vary from day to day. Drilling may occur for several days followed by a trip to replace a bit. Blowout preventers are regularly tested. The mud pumps do not run continuously, etc. Therefore, a single survey cannot adequately define the sound pressure levels to which workers may be exposed. Furthermore, many of the noises are intermittent. The setting of brakes on the drawworks, the releasing of pipe strings during a trip, and the use of makeup tongs are just a few of the sources that generate intermittent noise. Refinements to the surveys could include measuring the duration and repetition frequencies of intermittent noises.

The collection of sound pressure level data on production platforms can probably be accomplished in a single survey of the platform. There are fewer operating changes on a production platform which might affect the SPL contours than on drilling rigs. However, if a crane or sandblaster is being used, or a workover is being performed, there could be significant variations in the measured SPL's. Ideally, a survey should be repeated several times to achieve complete representation of all sources.

Each drilling rig or production platform survey will require approximately one 12-hour day for 2 men. Basically, the data will be collected using precision sound level meters complying with and calibrated according to applicable American National Standards Institute documents.

The sound pressure levels will be measured in dBA at approximate operator ear level. The contour data will be augmented with octave band levels measured near typical sound sources which are found on offshore structures. As an example, octave band levels will be taken near reciprocating compressors, turbines, centrifugal compressors and

pumps. These octave band measurements will provide a base of typical sound levels and frequency distributions which can be of value to later efforts in assessing the potentials for noise abatement. In addition, at a later date the initial data could be combined with acoustic treatment information to create case histories for use by industry.

2. Exposure Time Measurements

Because exposure times will vary depending on the job assignments for a particular day, the worker exposure times should be partially based on job descriptions. It should be possible to make a reasonable estimation of exposure times based on discussions with employees and supervisors. Figure VI.2 is a sample form which could be used to collect exposure data. Using this form, either the worker or his supervisor would identify specific tasks, the locations or the platform where these tasks are performed, and the time expended at that location during a shift. To validate the estimated exposure time, time-motion studies should be conducted on several individuals.

Job Title

Duty/Responsibility	Location	Time Expended Per Shift

FIGURE VI.2. EXPOSURE TIME

Because no measurement of the sound pressure level is required during the time-motion studies, this effort could be accomplished in conjunction with the dust and vapor measurements that have been included in the Phase II Experimental Plan. Whenever an individual is monitored for exposure to these airborne contaminants, his motion is recorded by an observer. This same time-motion information can supplement specific noise exposure time measurements.

VI.5.3 Data Analysis

The data collected on drilling rigs and production platforms can be analyzed to determine compliance with guidelines. The SPL contours can be reviewed to determine if noise levels measured at specific locations meet the guidelines. For example, the guidelines may specify that the sleeping areas should be less than 50 dBA. Compliance can be determined by simply examining the pressure contours obtained. Compliance with exposure guidelines can be determined by combining the sound pressure data with worker exposure times at specific locations. Any of several approaches can be used to combine this data. The effective 24-hour sound level can be calculated. Alternatively, the noise dosage can be calculated and presented similar to Table VI.1. The exact method(s) will be determined based on the type of criteria selected as guidelines.

VII. SUMMARY AND CONCLUSIONS

VII.1 Summary

The objectives of the Phase I Crew Exposure Project for offshore drilling and production facilities have been achieved.

A background study was performed that included a search of the technical literature, contacts with U. S. and foreign organizations concerned with offshore operations, a review of present and pending state and federal regulations that affect offshore operations, and several visits to offshore drilling rigs and production platforms.

The literature search uncovered several references with information about different offshore platform designs and equipment, drilling and production operations, and the chemical ingredients added to drilling fluids to provide the desired physical and chemical properties for different drilling conditions. However, very little information was found concerning the exposure of drilling and production crew members to potentially hazardous aerosols (mists, dusts, gases and vapors) and liquids during their work activities. Contacts with U. S. and foreign industry and government organizations indicated that there was no duplication of effort between the data gathering and research program of this and other investigations. Crew exposure to noise was subsequently added to the scope of the project, and a literature search was conducted to obtain information from published sources.

The background visits to offshore facilities provided firsthand information concerning (1) the size of the crew, their work schedules and duties, (2) the types of equipment which may emit potentially hazardous aerosols, and (3) the types of operations during which crewmen may come into contact with potentially hazardous materials. A total of eight offshore production platforms and seven drilling rigs were visited during the Phase I background study. A limited number of vapor concentration measurements were made on two of the drilling rigs and four of the production platforms to aid in the identification of contaminant emission sources.

The information obtained during the background study formed the basis for developing an experimental plan to characterize the concentration distribution of contaminant emissions in the workplace, and to assess the exposure of crewmen to these contaminants. However, more information was needed about (1) the composition of gas and vapor emissions from production platforms, (2) the emission of gases, vapors and dust during drilling, and (3) dermal contact with the drilling fluid by drilling crew personnel. Two additional offshore observations were performed that provided this essential information, and also demonstrated the feasibility of performing a component analysis of gas and vapor samples by gas chromatograph while offshore.

The experimental plan proposed methods for the identification and characterization of emission sources, and for both area and personal sampling to determine the hazard potential in each of the following areas:

- o the exposure of drilling crew members to respirable dust while adding dry drilling fluid materials to the drilling mud in the mud make-up area,
- o the exposure of drilling crew members to respirable gases and vapors released from the drilling fluid at the shale shaker and mud pits,
- o the dermal contact of drilling crew members with the drilling mud and with drilling mud ingredients that may lead to sensitization and irritation of the skin,
- o the exposure of production crew members to respirable gases and vapors emitted from the production equipment. Special attention is paid to enclosed spaces such as compressor rooms and work rooms.

An experimental plan was also developed to characterize the exposure of crewmen to noise while working offshore. Implementation of the noise test plan will be performed during Phase II of the Crew Exposure Project.

The experimental plan for aerosol and liquid exposure was given a trial implementation during a seven-day observation that included both drilling and production facilities on a total of four offshore facilities. All fugitive and major emission sources of dusts, vapors and gases were identified and characterized. Personal exposure to respirable dust was measured for both a roughneck and an observer during mud mixing operations. Levels of hydrocarbon gas and vapor concentration were determined near the shale shaker on the drilling rig, and in a fuel gas compressor room, and downwind of an oil flotation cell (used to clean produced water before it is discharged into the sea) on the production platforms. The activities of the drilling floor crew were observed to provide documentation of dermal exposure to the drilling fluid.

The results of the trial test plan implementation are, of course, specific to the actual platforms that were visited. Other platforms will differ in design, equipment, operation procedures, and in the provision and use of personal protective equipment (such as dust masks). Drilling fluid composition (water base or oil base mud) will also be site specific. Drilling floor procedures and rig "housekeeping" may also vary greatly from one rig to the next. On the other hand, the types of hydrocarbon gas and vapor emissions encountered on the production platforms should not be significantly different from one site to the next. Therefore, in presenting the conclusions of the Phase I Crew Exposure Study - Offshore, an attempt has been made to identify those results that may be generally true of the offshore industry. Areas where additional observations are

needed before definitive conclusions can be drawn are also identified. It should be noted that in the aggregate, observations and measurements were conducted on 13 offshore production platforms and 11 drilling rigs during the entire Phase I effort.

VII.2 Conclusions

The conclusions presented here pertain solely to the scope of this project, and to the documentation and measurement activities conducted during this project. Unless it is indicated otherwise, the conclusions should not be generalized or construed to be typical of the offshore industry.

- o This study does not duplicate any other known work that is being conducted in the U. S. or abroad. Literature searches and direct contacts support this conclusion.
- o Most emissions of contaminant gases and vapors on offshore production platforms are fugitive emissions from valves, flanges, threaded connections, and poorly sealed gaskets. The gas or vapor concentration at the emission source may be quite high, approaching 100%. However, the area of the source is usually very low, ranging from a "pin-hole" to 1 mm². Therefore, the emission rate from typical fugitive emission sources is also low.
- o The typical fugitive emissions found in compressor rooms, well head areas, turbine rooms, fuel gas engine installations, oil and oil/water transfer pumps, and oil/water/gas separation facilities on production platforms consist of a mixture of hydrocarbon gases and vapors. The concentration distribution of these emissions is usually typical of natural gas, with 85 to 95% methane and decreasing amounts of ethane, propane, butane, pentane and hexane.
- o At a typical fugitive emission source, the concentration of gas may be high enough to constitute a flammability hazard.
- o At a typical fugitive emission source, the concentration of gas may be high enough to constitute an asphyxiation hazard. However, if the fugitive emission rate is much lower than the human respiration rate, the inhaled contaminant gases would be diluted with air from the region around the source and might not present a hazard.
- o At a typical fugitive emission source, the concentration of individual hydrocarbon gases and vapors (butane, pentane, and hexane) may exceed the TLV-TWA level for toxicity hazards. However, if the fugitive emission rate is

much lower than the human respiration rate, these inhaled contaminant gases would be diluted with air from the region around the source and might not present a hazard.

- o Fugitive emissions of gas from typical sources located in well ventilated areas will be diluted by the wind, or ventilation air flow, to concentration levels that are below the maximum permissible levels for toxicity, flammability and asphyxiation by current standards.
- o Fugitive emissions of gas from typical sources located in poorly ventilated areas or enclosed spaces may cause the gas concentration level in the area or space to increase with time and approach or exceed the maximum permissible level.
- o Existing USGS regulations require that gas sensors be used in all inadequately ventilated, enclosed, high hazard areas. Also, a fuel gas odorant or an automatic gas detection and alarm system are required in enclosed, continuously manned areas.
- o Existing USGS regulations require that electrical equipment and installations conform to the standards set forth in the National Electrical Code. Thus, explosion-proof housings for electrical circuits, equipment and connections are required in hazardous areas.
- o Area samples of contaminant gases collected in a gas compressor room and downwind of an oil/water flotation cell on a production platform gave gas concentration values that were below the maximum permissible levels for toxicity, flammability and asphyxiation by current standards.
- o The most likely contaminant emissions on an offshore drilling rig are (1) dust released into the air during mud mixing activities in the mud make-up room, and (2) gas and vapor evolved from the drilling fluid at the shale shaker and mud pit.
- o Dust is emitted into the air above the bulk solids hopper when the roughneck slits open a bag of dry drilling fluid material and empties the bag into the hopper. Some materials are finely ground and emit a cloud of dust. Other materials (particularly caustic soda and ground nut shells) are coarsely ground and emit very little dust. The technique used by the roughneck in emptying each bag has a strong influence upon the amount of dust that is emitted into the air. Good ventilation of the mud mixing area is important to prevent accumulation of dust in the air.

- o Measurements of the respirable dust concentration in the breathing zone for a roughneck and an observer during mud mixing, indicated that the concentration levels of dust were below the maximum permissible levels for nuisance particulate matter by current standards. This result may not apply to all other drilling rigs.
- o Under normal operating conditions, gas from underground formations is prevented from entering the drilling fluid by the hydrostatic head of the drilling fluid column. However, when gas cutting of the drilling mud does occur, formation gas will be released at the shale shaker until the mud weight and formation pressure are balanced. Good ventilation of the shale shaker room (if enclosed) is important to prevent the accumulation of gas.
- o Measurement of contaminant gas in shale shaker areas during drilling with water base mud indicated that the concentration level was below the maximum permissible level by current standards. These areas were well ventilated to prevent gas accumulation. This result may not apply to rigs with shale shakers located in poorly ventilated rooms.
- o Measurements of contaminant gas in shale shaker and mud pit areas during drilling with an oil base mud indicated that the concentration level was acceptable by current standards. The contaminant gas consisted of vapor from the diesel fuel base for which a TLV-TWA value of maximum permissible concentration has not been defined.
- o Dermal contact with some commonly used drilling fluid materials is known to cause skin burns (from caustic soda) and irritation of existing skin wounds (calcium chloride, calcium bromide). However, other drilling fluid materials may contain ingredients (sometimes as impurities) that can produce skin sensitization and irritation from dermal contact. A preliminary list of these ingredients and their dermal exposure effect has been prepared. Additional effort is required to complete this list and to cross-reference it to a list of drilling fluid materials.
- o When caustic soda is being handled, goggles should be worn to prevent any possible contact with the eyes. Caustic soda, and other alkaline substances are severe eye hazards.
- o Extensive contact of water base drilling fluids with the clothing and skin of the drilling floor crew members was not observed. The use of good operating procedures when adding new lengths of drill pipe to the drill string can

minimize the potential for skin contact with the drilling fluid. These include (1) having a check valve in the drill collar to prevent the flow of mud backup through the drill pipe, (2) allowing the mud pumps to stop completely before breaking the connection between drill pipe and kelly, (3) washing the drill pipe and rotary table with drill water before breaking the connection, (4) maintaining good housekeeping standards and keeping the drains open, and (5) wearing long-sleeve shirts and gloves. Operating procedures and drill floor standards for housekeeping will vary from one rig to the next.

- o Any crew member who has a skin wound or broken place on exposed hands and arms should wear impervious gloves and forearm coverings. Many substances like drilling mud, chemicals and fuel will severely irritate the abraded skin and sub-tissue.
- o The observation of drilling with an oil base mud indicated that the potential for skin contact could be greater than for water base mud. This is because the oil base mud is not water soluble and could not be washed from the drill pipe and rotary table before the drill pipe to kelly connection was broken. The drilling floor became slippery and accidental contact with the drilling fluid could not be avoided.
- o Diesel fuel used as the oil phase in oil base drilling fluid is only a mild eye irritant, and is not a sensitizer, mutagen or genetically active agent. However, if skin contact with oil base drilling fluid is prolonged by more than 20 to 30 minutes by mud wet clothing or mud contaminated gloves, severe irritation or blistering of the skin may result.

APPENDIX A

CATEGORIZED BIBLIOGRAPHY

CATEGORIZED BIBLIOGRAPHY

"A CREW EXPOSURE STUDY--PHASE I"

- A - TOXICITY, TOXICOLOGY
- B - PLUME AND PLUME MODELS
- C - SAMPLING PROCEDURES AND EQUIPMENT
- D - OFFSHORE EMISSIONS STUDY
- E - EXPLOSION MODELS
- F - CONTROL OF HYDROCARBON EMISSIONS, DUSTS
- G - DISCHARGING OF HAZARDOUS WASTES FROM
PLATFORMS
- H - AEROSOL
- I - URINE/BLOOD SAMPLING
- J - PLATFORM DESIGN (SAFETY RELATED)

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APPENDIX B

CLASSIFICATION OF OFFSHORE DRILLING
RIGS AND PRODUCTION PLATFORMS

Drill Ship and Drill Barge

Drill ships and drill barges may have the appearance of conventional ships and barges. Figure B.1 is an artist's view of a drill ship, and Figure B.2 is the general arrangement of a posted drill barge. Drill ships are utilized most often in relatively calm, medium depth water. Posted drill barges are used in shallow water where the hull can be submerged to rest on the bottom of the waterway. Floating drill barges are used in shallow water with most of the drilling support equipment below the deck as on a drill ship.

Jack-Up Drilling Platform

Jack-ups are steel structures with watertight hulls that serve as a vessel while under tow. Figure B.3 is a general view of a jack-up. Once the jack-up is on location, the legs are lowered to the sea bed and the hull is raised out of the water. Most of the machinery is located in enclosed rooms below the main deck, as can be seen in Figure B.4. Jack-ups are widely used as shallow water drilling units and are popular because of their low operating expense and stability.

Semi-Submersible Drilling Platform

The semi-submersible, shown in Figure B.5, is a floating unit that is stabilized by ballasting its pontoons and columns. They are held in position by chains, anchors, and sometimes dynamic positioning. Some semi-submersibles are equipped with thrust systems to aid in transporting and assistance in dynamic positioning. This platform is by far the most stable floating unit and is used in deep, rough water.

Submersible Drilling Platform

A submersible is composed of a lower hull (caisson), supporting columns, and a superstructure as shown in Figure B.6. Submersibles are very

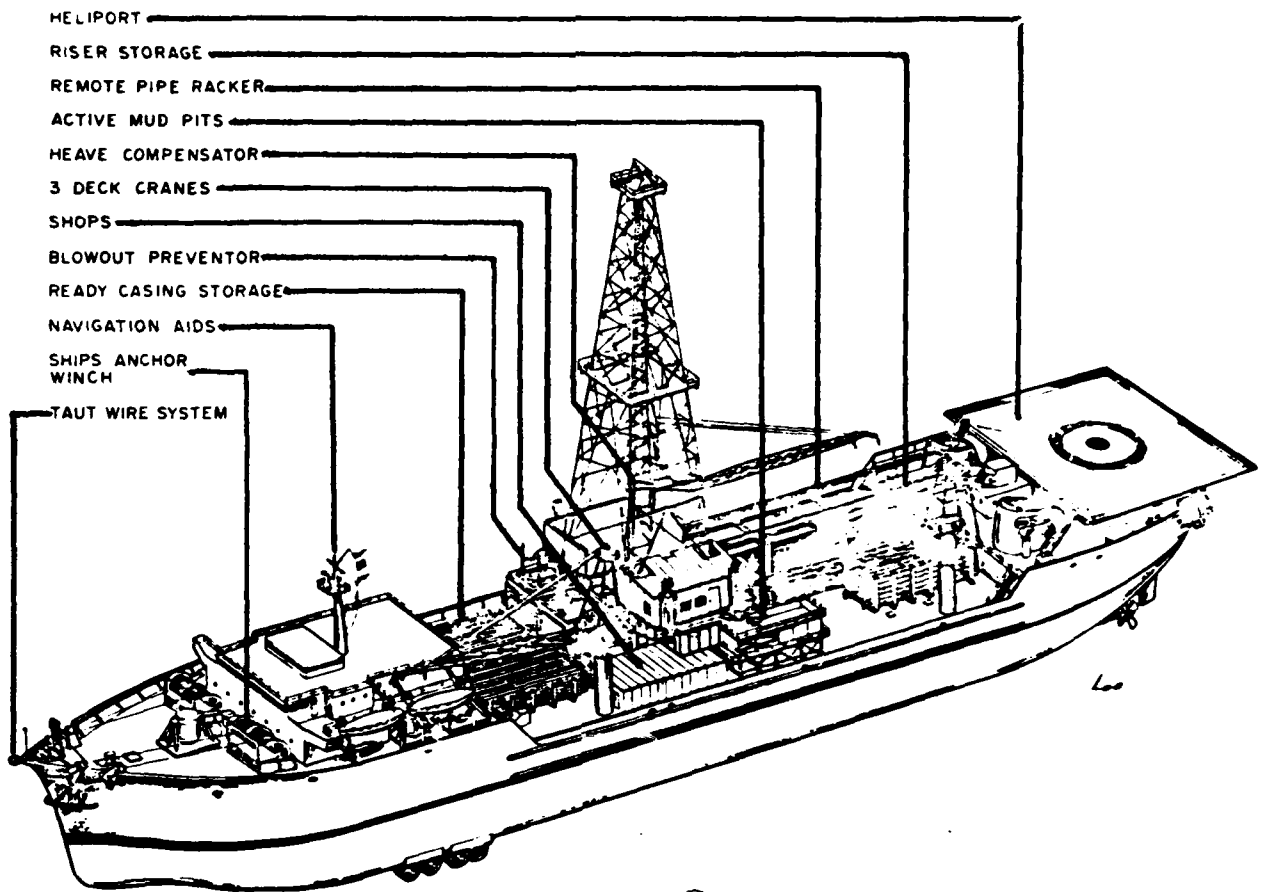


FIGURE B.1. DRILL SHIP

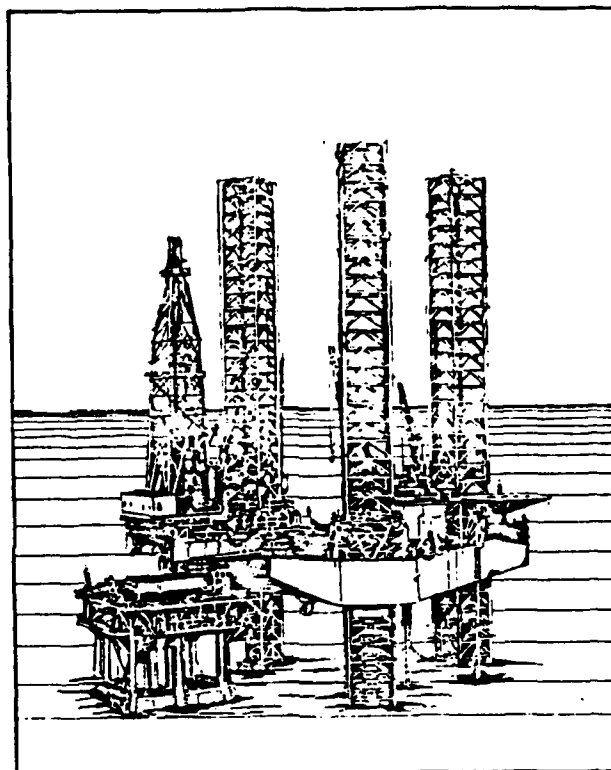


FIGURE B.3. JACK-UP PLATFORM

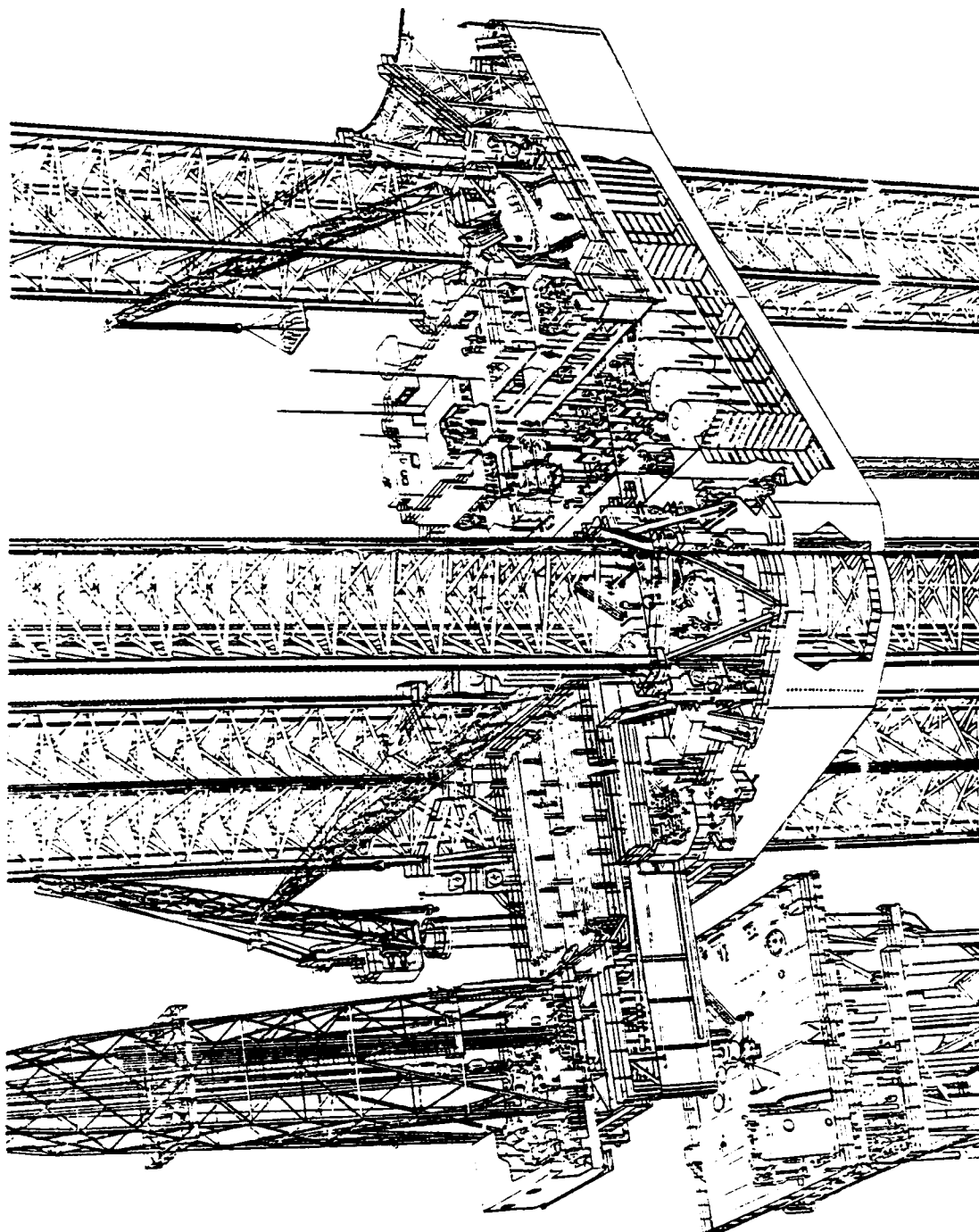


FIGURE B.4. ANATOMY OF A JACK-UP

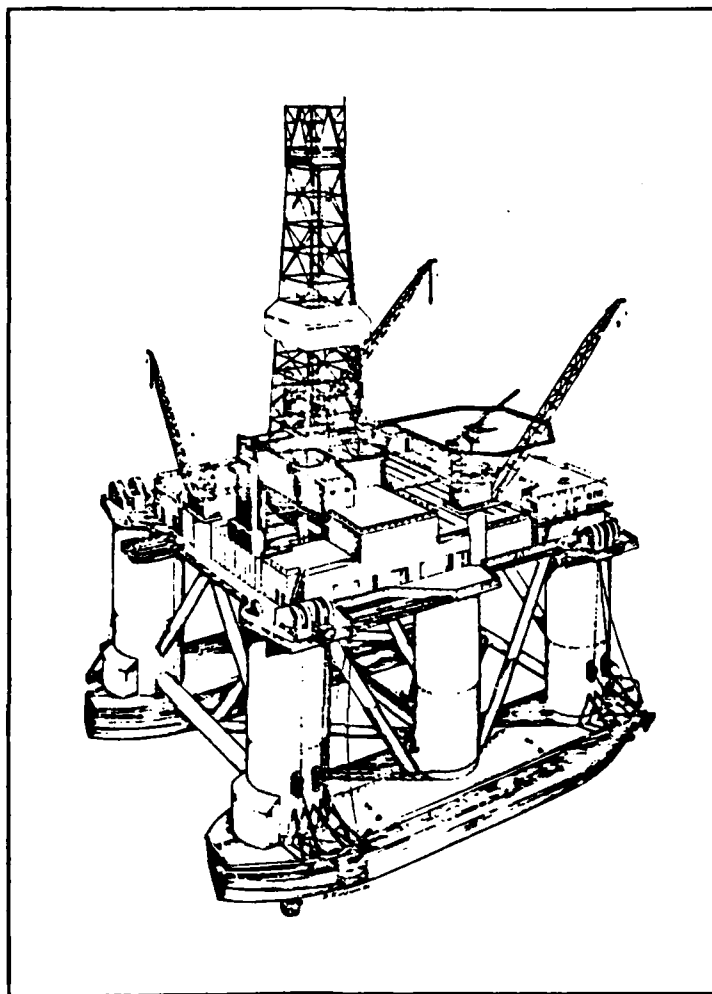


FIGURE B.5. SEMI-SUBMERSIBLE

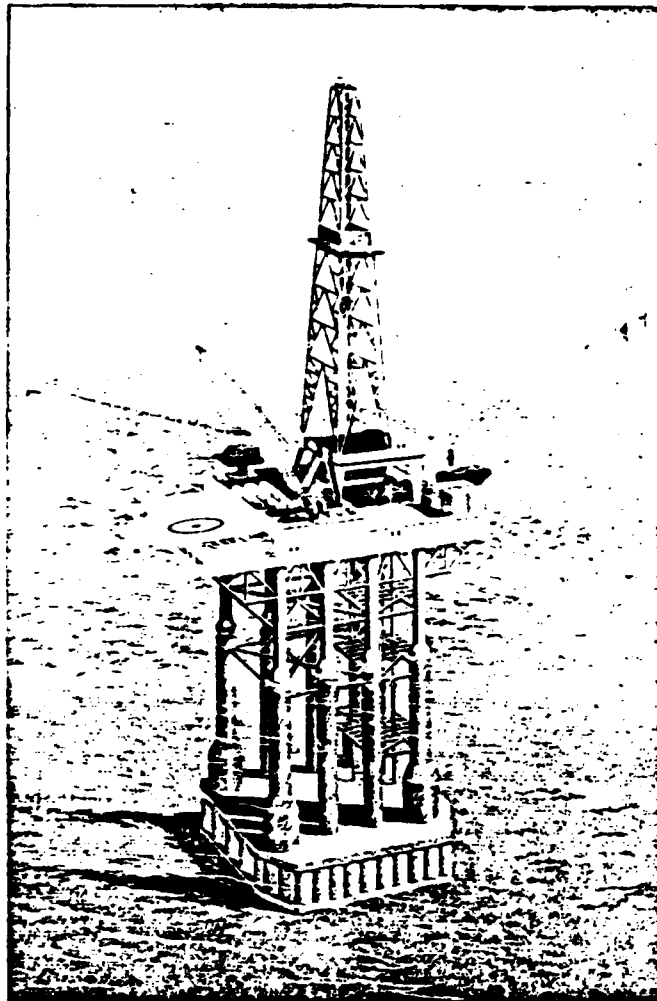


FIGURE B.6. SUBMERSIBLE

stable, but are expensive and hard to move. For these reasons, there are very few on service or under construction.

Jacket-Type Drilling/Production Platform

A jacket-type platform is a permanent template-type steel structure and is composed of three major components: the jacket, the piles, and the superstructure. Figure B.7 is an overall view of a jacket-type platform. The jacket is prefabricated in a yard, towed on a barge to the location, and dropped to the sea bed. Piles are then driven through tubular legs to secure the jacket permanently to the sea floor.

The superstructure is composed of prefabricated modules. These modules are placed on top of the secured jacket by crane barges. Since they are well above the maximum wave line, the construction of these modules provides a rather open environment around the machinery.

Both drilling and production operations may take place simultaneously on a jacket-type platform. The drilling rig is located on the top deck of the platform, with the wellhead area and separation equipment on a lower level. The drilling packages are removed after the drilling operation is completed.

Gravity, Tension Leg, Articulated Column, and Guyed Tower

Figures B.8, B.9, B.10, B.11, and B.12 are diagrams of steel gravity, concrete gravity, tension-leg, articulated column, and guyed tower platforms, respectively. Because they are not commonly found in the U.S. coastal waters and because they present no unique features relative to crew exposure assessment, they will not be discussed, but are simply included for reference.

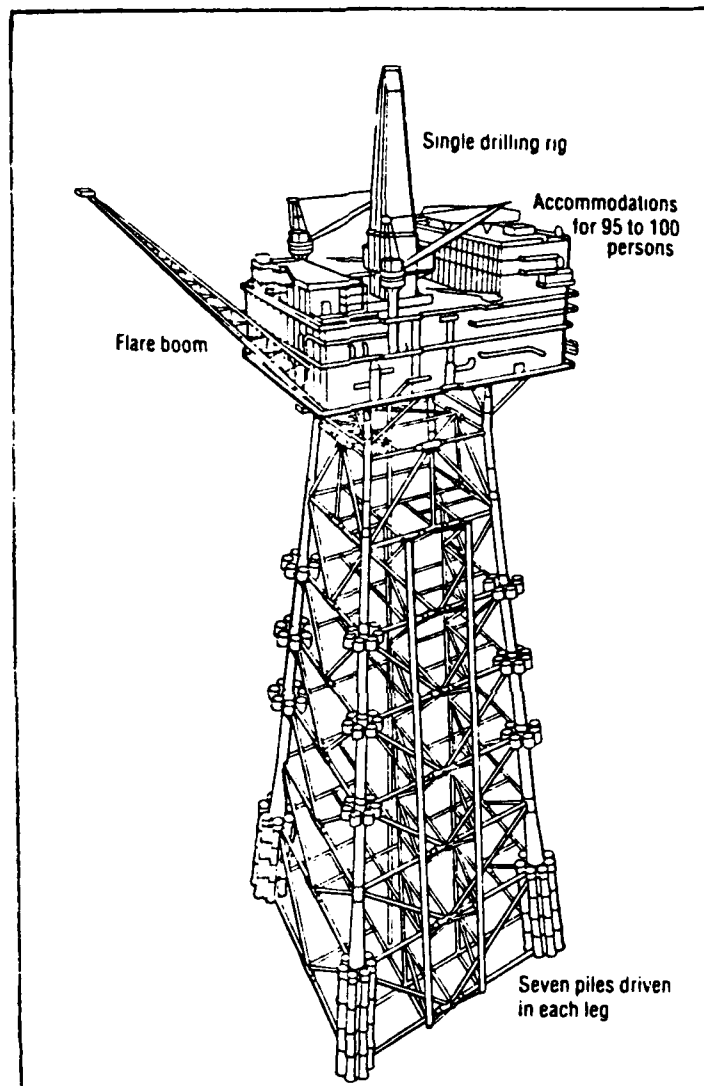


FIGURE B.7. JACKET-TYPE PLATFORM

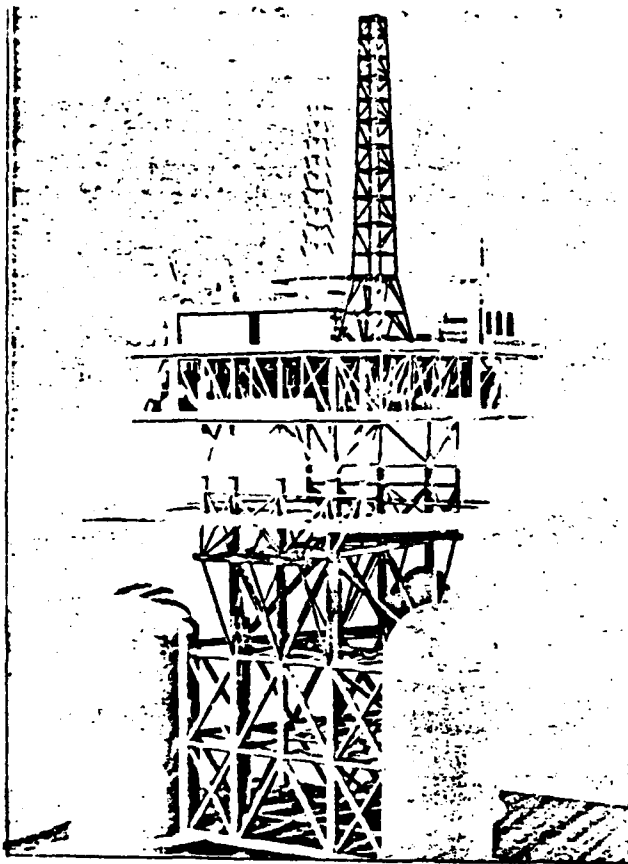


FIGURE B.8. STEEL GRAVITY PLATFORM

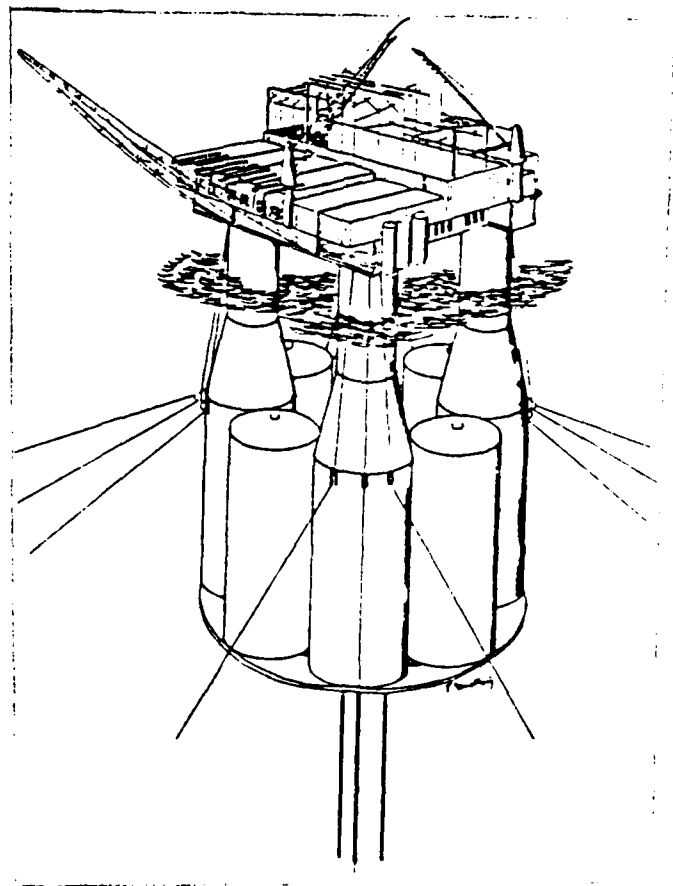
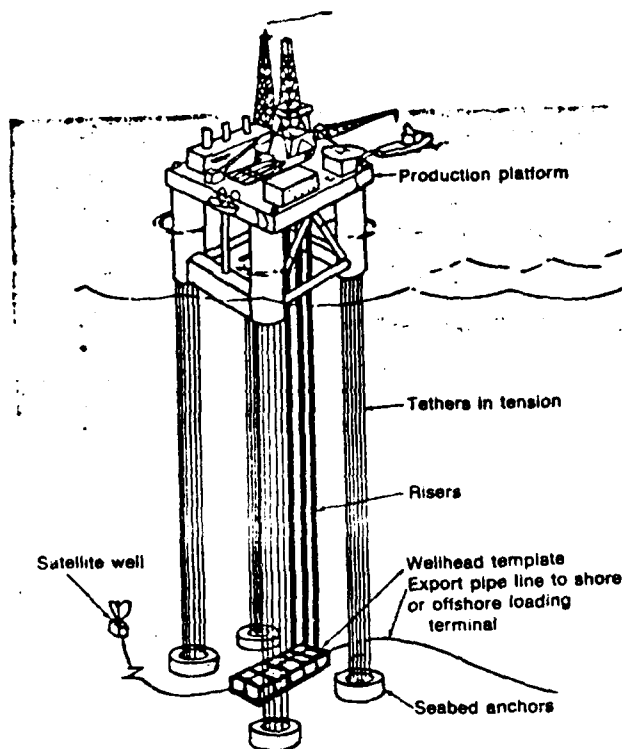


FIGURE B.9. CONCRETE GRAVITY PLATFORM



VERTICAL TENSION LEG PLATFORM

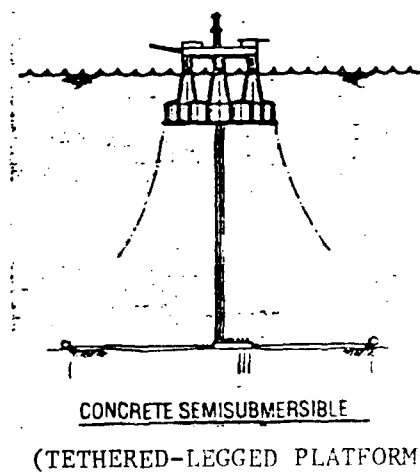
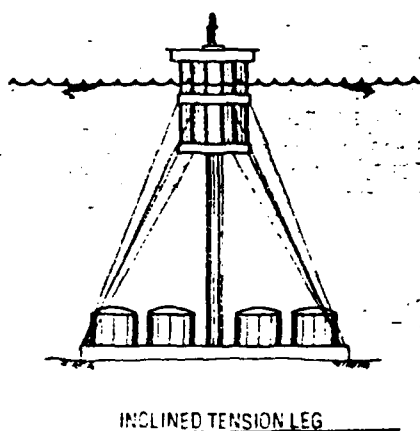


FIGURE B.10. TENSION LEG PLATFORMS

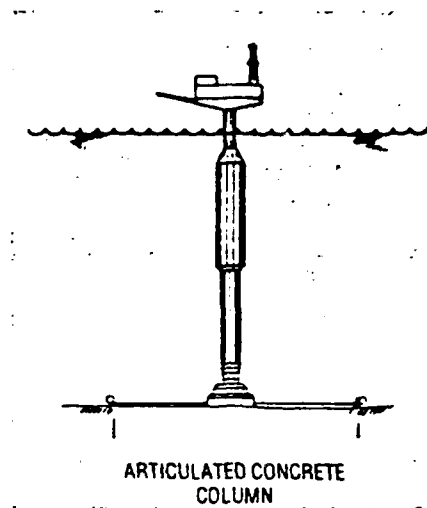


FIGURE B.11. ARTICULATED COLUMN PLATFORM

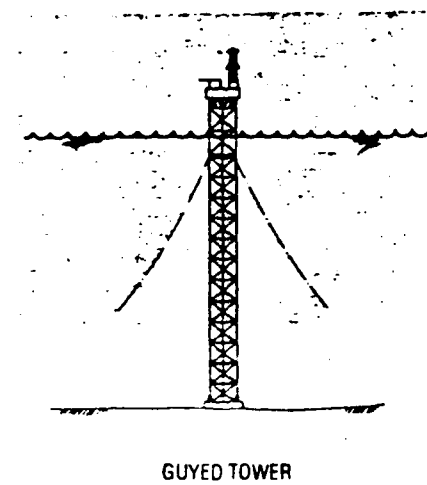


FIGURE B.12. GUYED TOWER PLATFORM

APPENDIX C

EQUIPMENT RELATED TO DRILLING
AND POTENTIAL HAZARDOUS SOURCES

EQUIPMENT RELATED TO DRILLING

Equipment	Purpose	Potential Hazardous Sources
<u>POWER GENERATING SYSTEM</u>		
Diesel Engine or Gas Turbine (Figure C.1)	To drive electric generators.	<ol style="list-style-type: none"> 1. Oil mist, as aerosol, of lubricating fluid. 2. Vapors from diesel day tanks and lube oil tanks while being checked or filled. 3. Hot engine exhaust products from exhaust stacks.
<u>DRILL FLOOR MACHINERY</u>		
Drawwork (Figure C.2)	Revolving drums for spooling the drill- ing line.	
Derrick (Figure C.3)	Drilling line goes over the crown block and through the traveling block hanging from the derrick. The travel- ing block carries the swivel, kelly, and drill pipes to perform the drilling.	
Rotary and Rotary Table (Figure C.4)	The rotary is equipped with a square or hexa- gonal kelly bushing which provides torque for the drilling pipe to cut through the formation.	
Drill String (Figure C.5)	Pipe attached to drill bit.	<ol style="list-style-type: none"> 1. Drilling fluid released from drill pipe when re- moving pipe from the well.
(Continued)		

EQUIPMENT RELATED TO DRILLING (Cont'd)

Equipment	Purpose	Potential Hazardous Sources
<u>DRILLING FLUID SYSTEM</u>		
Mud Storage Tank	Stores bulk mud.	
Storage House (Figure C.6)	Stores extra sacks of mud and dry chemicals. Sometimes located on deck open to environment.	1. Dust from chemicals during transporting of bags.
Surge Tank	Regulates the amount of mud input from mud storage tank.	
Mix Hopper (Figure C.7)	Mixes dry mud, water, dry chemicals, liquid chemicals and possibly oil. Driven by mud mixing pump.	1. Dust from chemicals being mixed.
Active Mud Pit	Muds routed from the mud hopper to the active mud pit which is equipped with mud agitators to maintain a uniform mixture.	1. Vapors, mists, and dusts from the mud mixture. 2. Outlets of mud pit room ventilation system.
Mud Pump (Figure C.8)	Pumps mud from active mud pits to the drill floor. Driven by electric motors.	
Shale Shaker (Figure C.9)	Separates large particles from drilling fluids after mud has been circulated through the well hole.	1. Vapors from drilling fluid. 2. Gases in drilling fluid brought up from well hole (e.g. H ₂ S). 3. Mud splatter causing skin contact.
Desander (Figure C.10)	Removes sand from the mud.	
Degasser	Removes gas from the mud.	
(Continued)		

EQUIPMENT RELATED TO DRILLING (Concl'd)

Equipment	Purpose	Potential Hazardous Sources
<u>DRILLING FLUID SYSTEM</u>		
Desilter (Figure C.11)	Removes fine solids from the mud.	
Mud Trough (Figure C.12)	Provides path for clean mud to travel, usually by gravity, to the reserve mud pit.	1. Vapors from drilling mud if trough is open.
Reserve Mud Pit (Figure C.13)	Temporary storage for mud until it gets transported to the active mud pit.	
<u>CEMENTING UNIT</u> (Figure C.14)		
Cement Tank	Store bulk dry cement.	
Mix Hopper	Mixes dry cement, water, and special chemicals as needed.	1. Dusts created during mixing.
Cement Pump	Transports mixed cement to drill floor.	

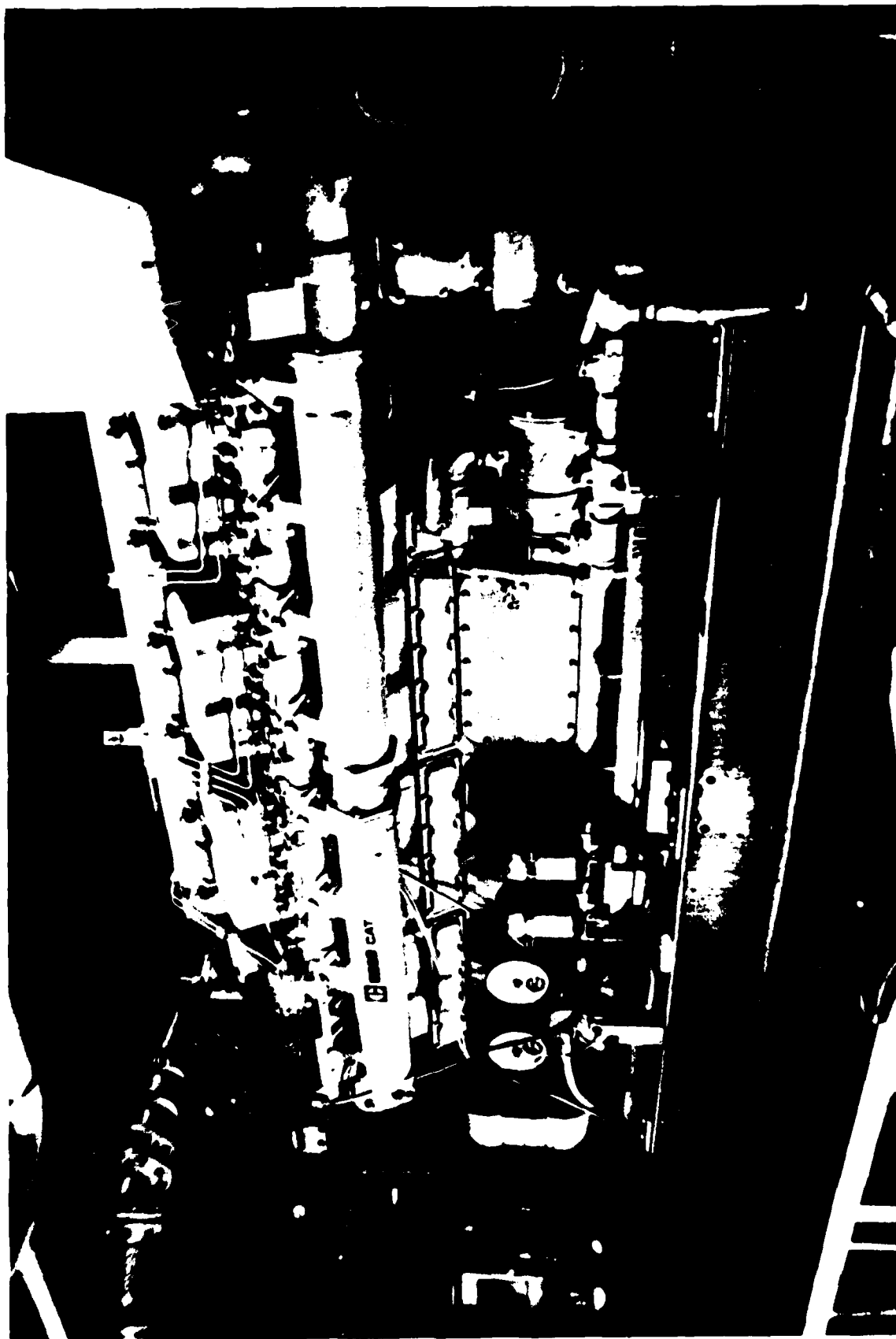


FIGURE C.1. DIESEL ENGINE

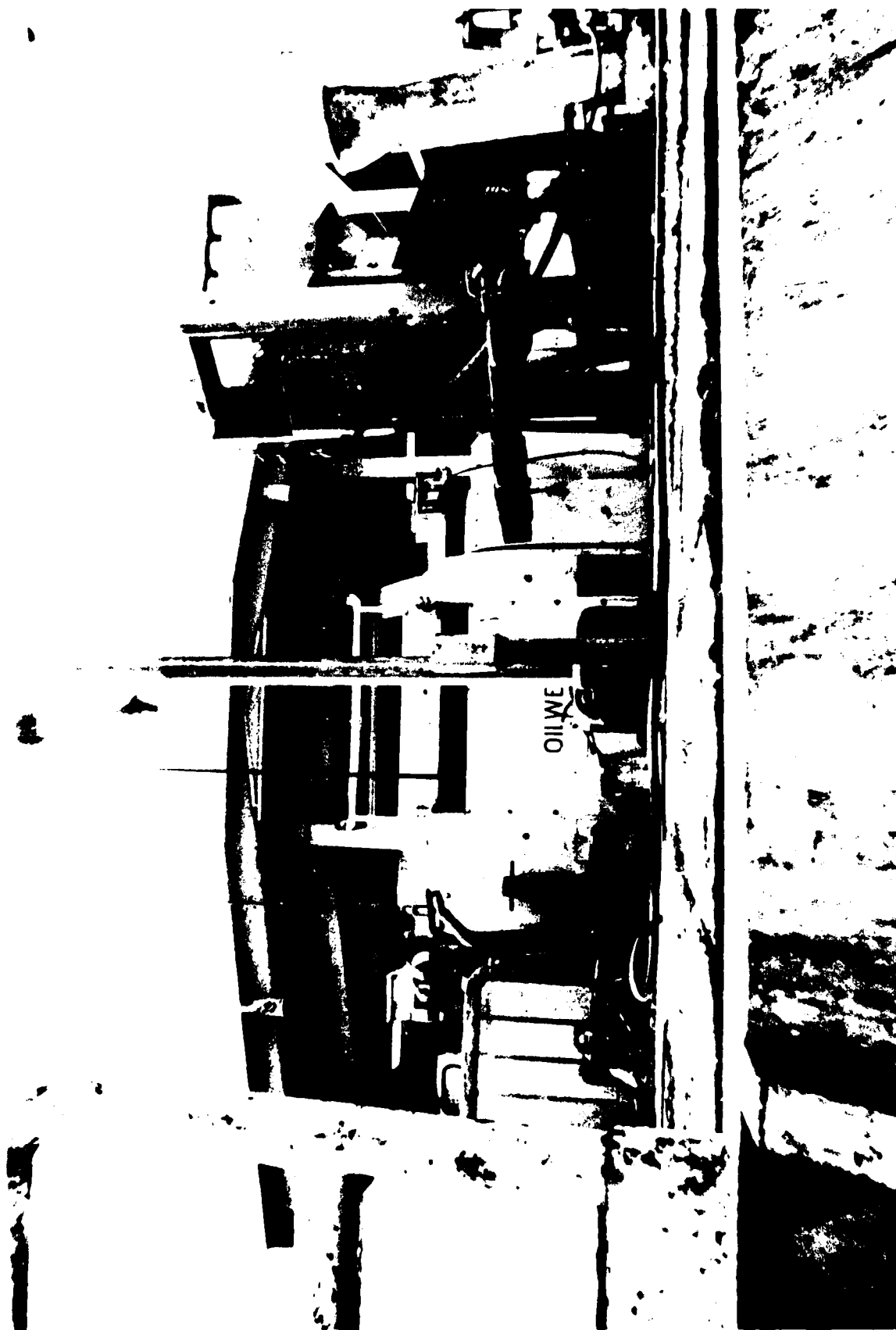


FIGURE C.2. DRAWWORK

1. CROWN BLOCK AND WATERTABLE
2. MAST
3. MONKEYBOARD
4. TRAVELING BLOCK
5. HOOK
6. SWIVEL
7. ELEVATORS
8. KELLY
9. KELLY BUSHING
10. MASTER BUSHING
11. MOUSEHOLE
12. RATHOLE
13. BACKUP TONGS
14. MAKEUP TONGS
15. DRAWWORKS
16. WEIGHT INDICATOR
17. DRILLER'S CONSOLE

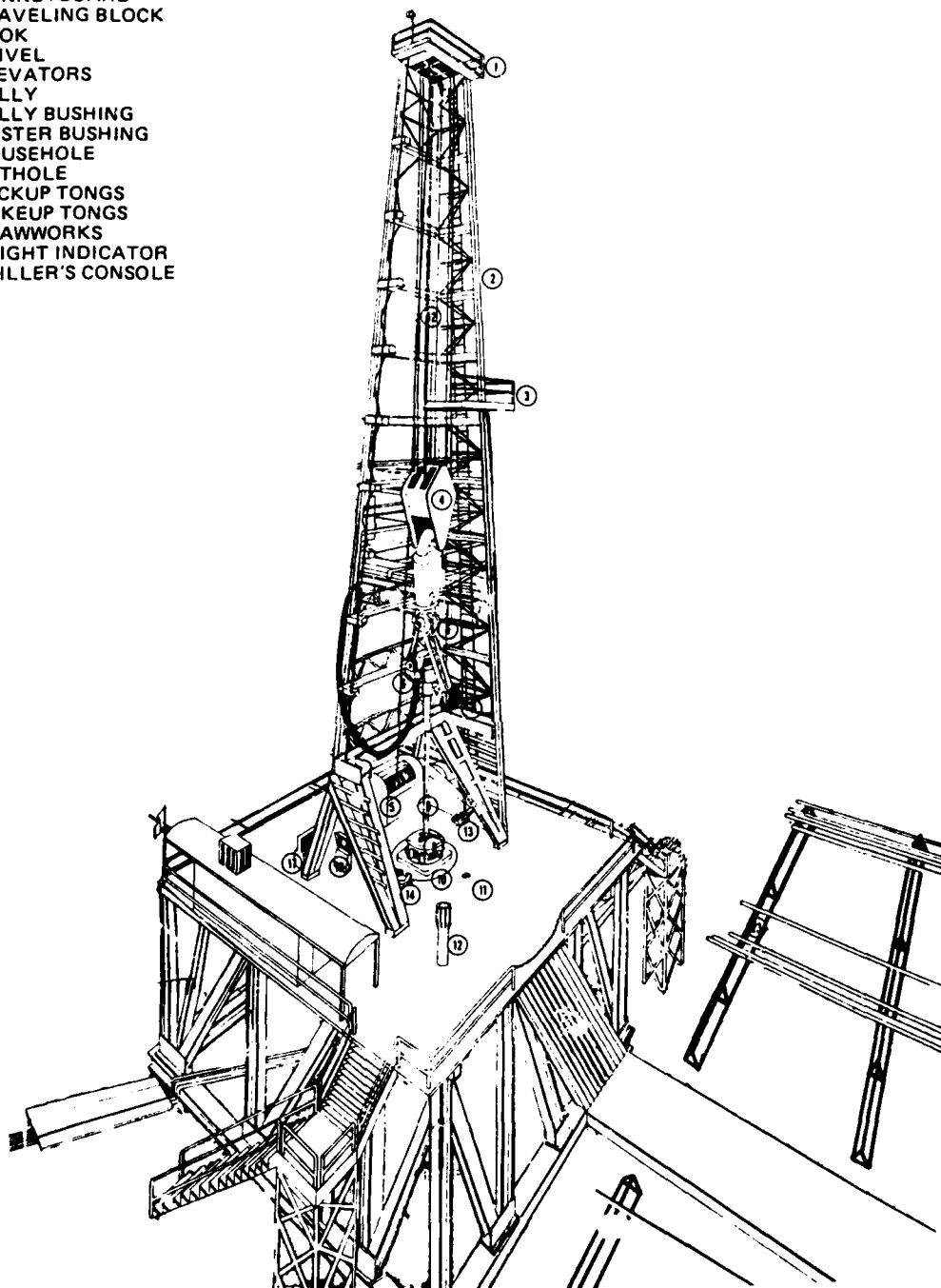


FIGURE C.3. DRILL FLOOR



FIGURE C.4. ROTARY AND ROTARY TABLE



FIGURE C.5. DRILL STRING



FIGURE C.6. CHEMICAL STORAGE



FIGURE C.7. MIX HOPPER



FIGURE C.8. MUD PUMP



FIGURE C.9. SHALE SHAKER



FIGURE C.10 DESANDER



FIGURE C.11. DESILTER

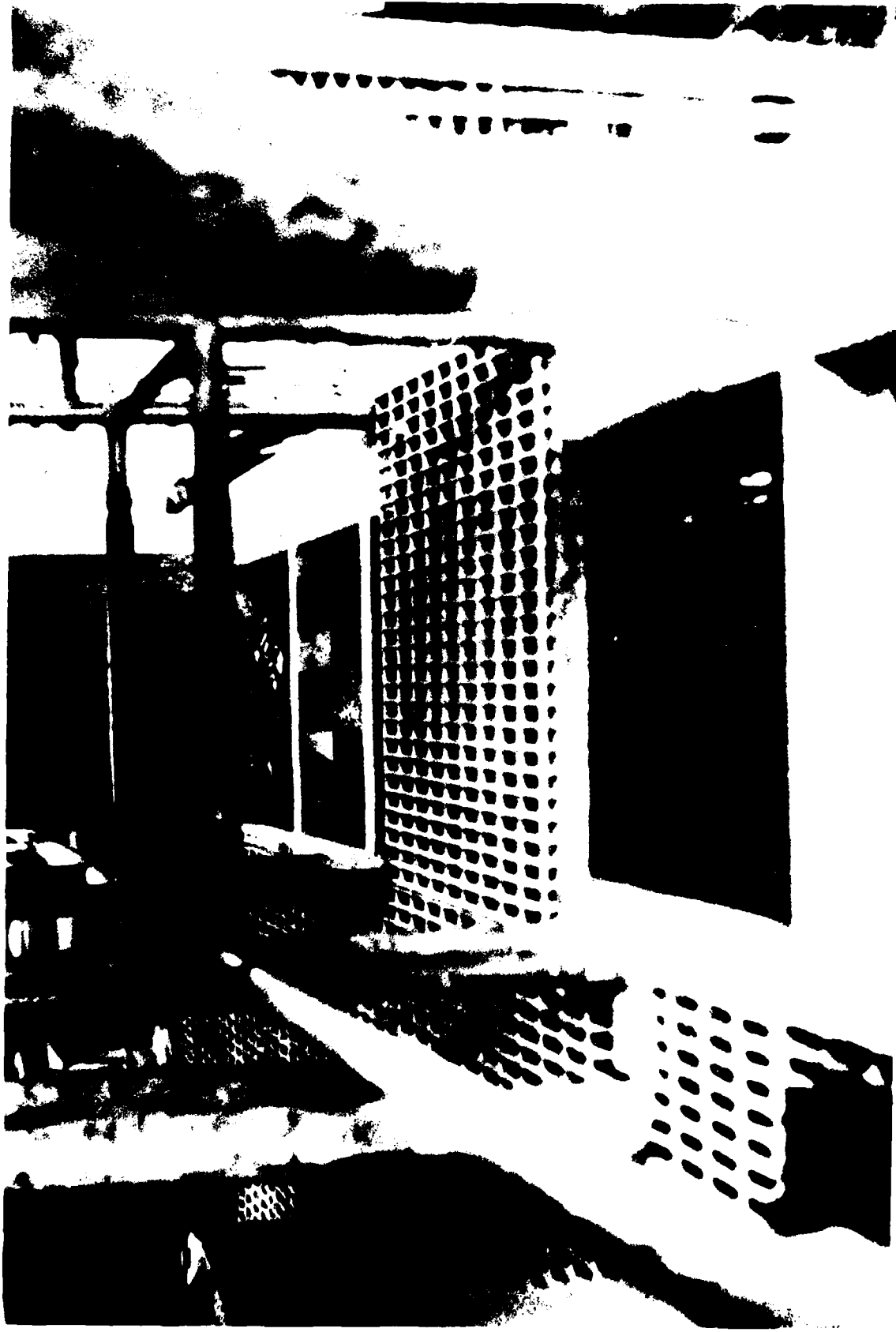


FIGURE C.12. OPEN MUD TROUGH

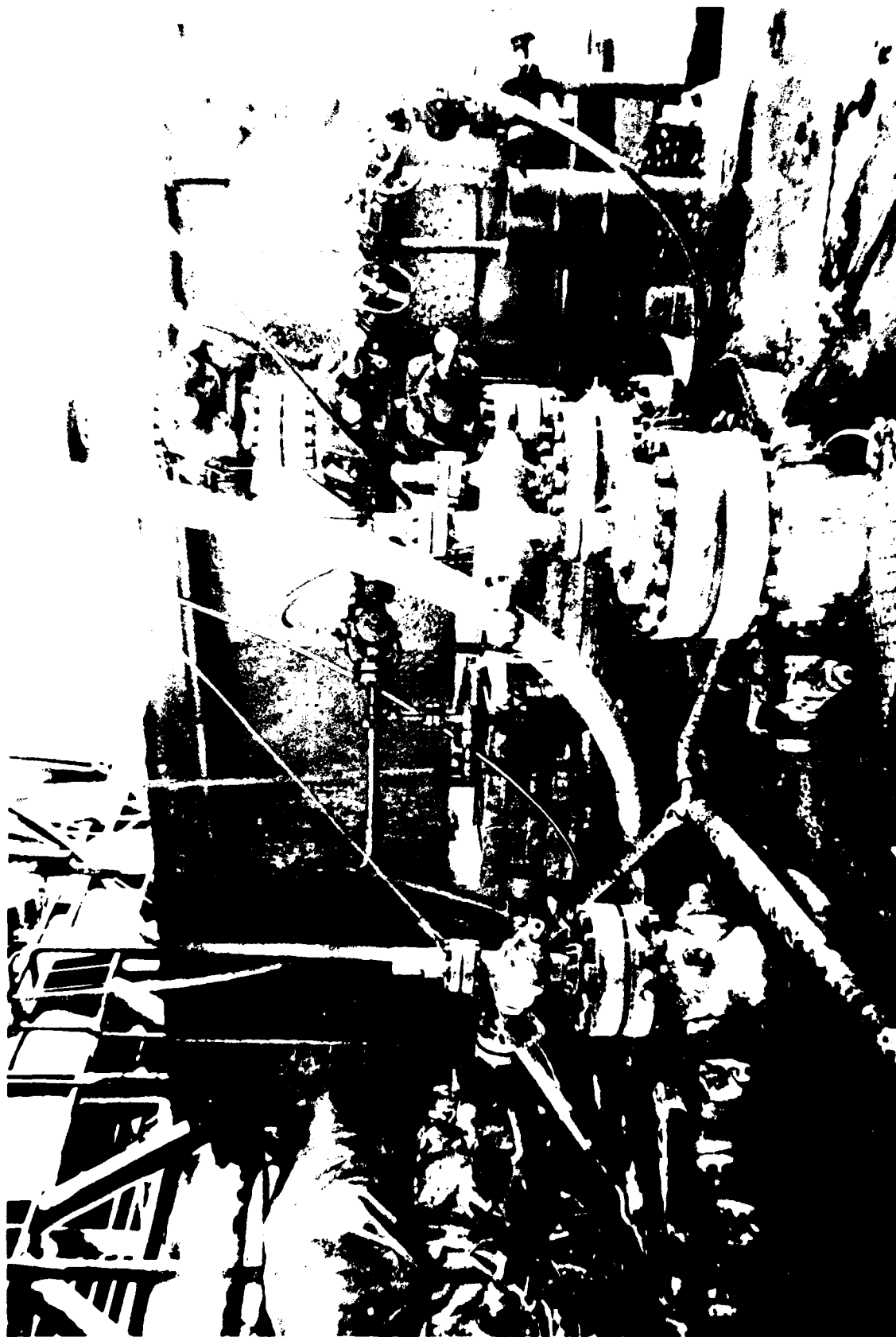


FIGURE C.13. CAPPED WELLHEAD WITH RESERVE MUD PIT IN BACKGROUND

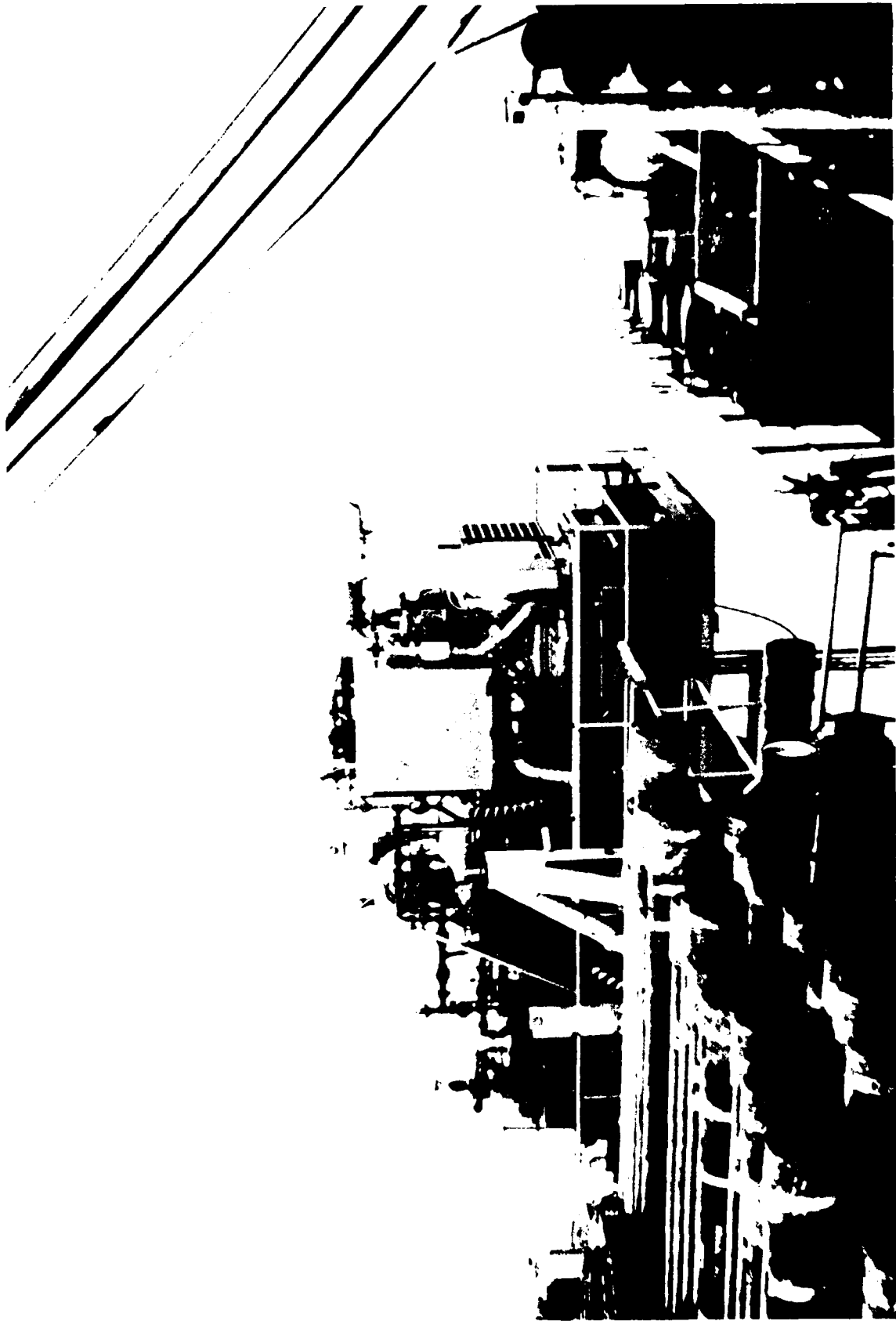


FIGURE C.14. CEMENTING UNIT

APPENDIX D

EQUIPMENT RELATED TO PRODUCTION
AND POTENTIAL HAZARDOUS SOURCES

EQUIPMENT RELATED TO PRODUCTION

Equipment	Purpose	Potential Hazardous Sources
<u>WELLHEAD EQUIPMENT</u>		
Wellhead (Figure D.1)	Controls the flow from a producing well.	1. Flange or valve leaks.
Manifolds (Figure D.2)	Directs the flow from each wellhead to outlets.	1. Flange or valve leaks.
Header	Receives flows from several manifold outlets and distributes them to the production system.	1. Flange leaks.
<u>HYDRATES PREVENTION EQUIPMENT</u>		
Heaters:		
Indirect Fired	Uses heat medium to transmit heat from heat sources to prevent hydrates formation in the product gas.	
Direct Fired	Uses gas or diesel fuel to prevent hydrates formation in the product gas.	1. Exhaust from burner.
Methanol Injection System	Injects methanol to prevent hydrates formation in the product gas.	1. Vent from the methanol storage tank.
<u>GAS PURIFICATION EQUIPMENT</u>		
Heat Exchanger	Attains optimum temperature for proper operation of the process. Also conserves and/or utilizes the heat content of the stream to reduce the external heat input required.	
Glycol System (Figure D.3)	Removes water vapors from gas by Absorption.	
(Continued)		

EQUIPMENT RELATED TO PRODUCTION (Cont'd)

Equipment	Purpose	Potential Hazardous Sources
<u>GAS PURIFICATION EQUIPMENT</u>		
Glycol Contact Tower (Figure D.4)	Removes water vapor from gas.	
Glycol Reboil	Reconcentrates diluted glycol by heating and driving off excess water.	1. Exhaust from heater.
Glycol Surge Tank	Provides an adequate reservoir of liquid in the glycol system to maintain a "steady state" process.	
Glycol Pump	Transports dry glycol to contact tower.	1. Packings may leak. 2. Drainage trough.
<u>POWER GENERATING SYSTEM</u>		
Diesel Engine or Gas Turbine	To drive electric generators.	1. Oil mist, as aerosol, of lubricating fluid. 2. Diesel day tanks and lube oil tanks while being checked or cleaned. 3. Outlets of engine exhaust system.
<u>GENERAL EQUIPMENT</u>		
Pig launch (Figure D.5)	Where pig is launched to clean pipelines.	1. Open launch while pig is being loaded.
Sump Area (Figure D.6)	Collects various liquids.	1. Open sump in enclosed areas.
(Continued)		

EQUIPMENT RELATED TO PRODUCTION (Concl'd)

Equipment	Purpose	Potential Hazardous Sources
<u>GENERAL EQUIPMENT</u>		
Secondary Recovery	Increases yield of product from a well.	1. Exhaust of degasser. 2. Compressor outlet used for gas lift system.
<u>PRELIMINARY SEPARATING EQUIPMENT</u>		
Separator: Three phase	Separates gas, oil, and water	1. Cleanout port for solids. 2. Open separator during maintenance.
Two phase (Figure D.7)	Separates gas from liquid.	1. Cleanout port for solids. 2. Open separator during maintenance.
Test Separator: (Figure D.8)	Installed at the beginning of the flow line to check properties of well fluid.	1. Sample test area.
<u>OIL-WATER SEPARATING EQUIPMENT</u>		
Freewater Knockout	Separates free water from the oil	
Flotation Cell (Skimmer) (Figure D.9)	Separates oil and water by gravity.	1. Vent of the flotation cell. 2. Open cell during maintenance.
Wet Oil Tank		1. Vent of the wet oil tank. 2. Open tank during maintenance.

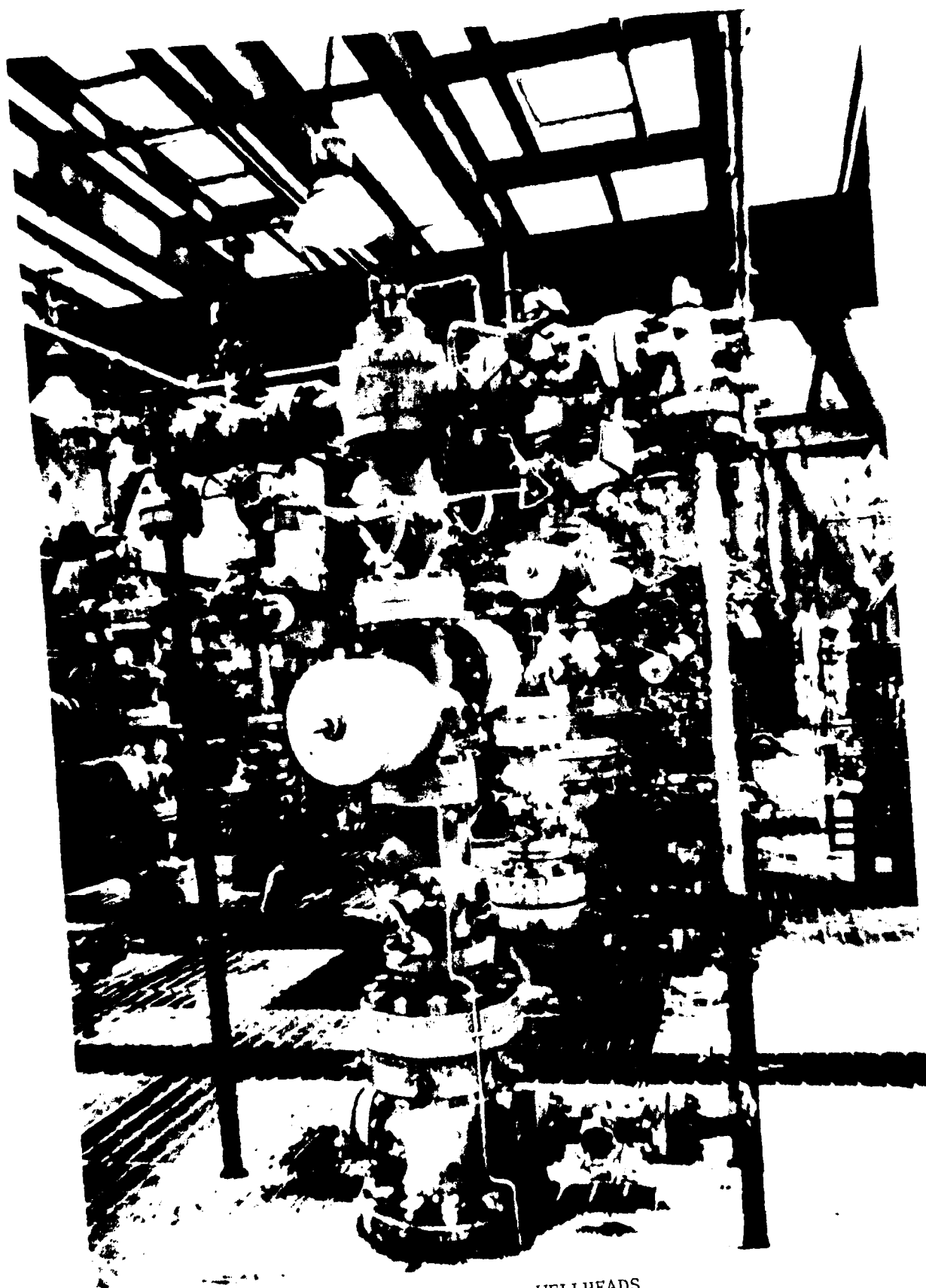


FIGURE D.1. WELLHEADS

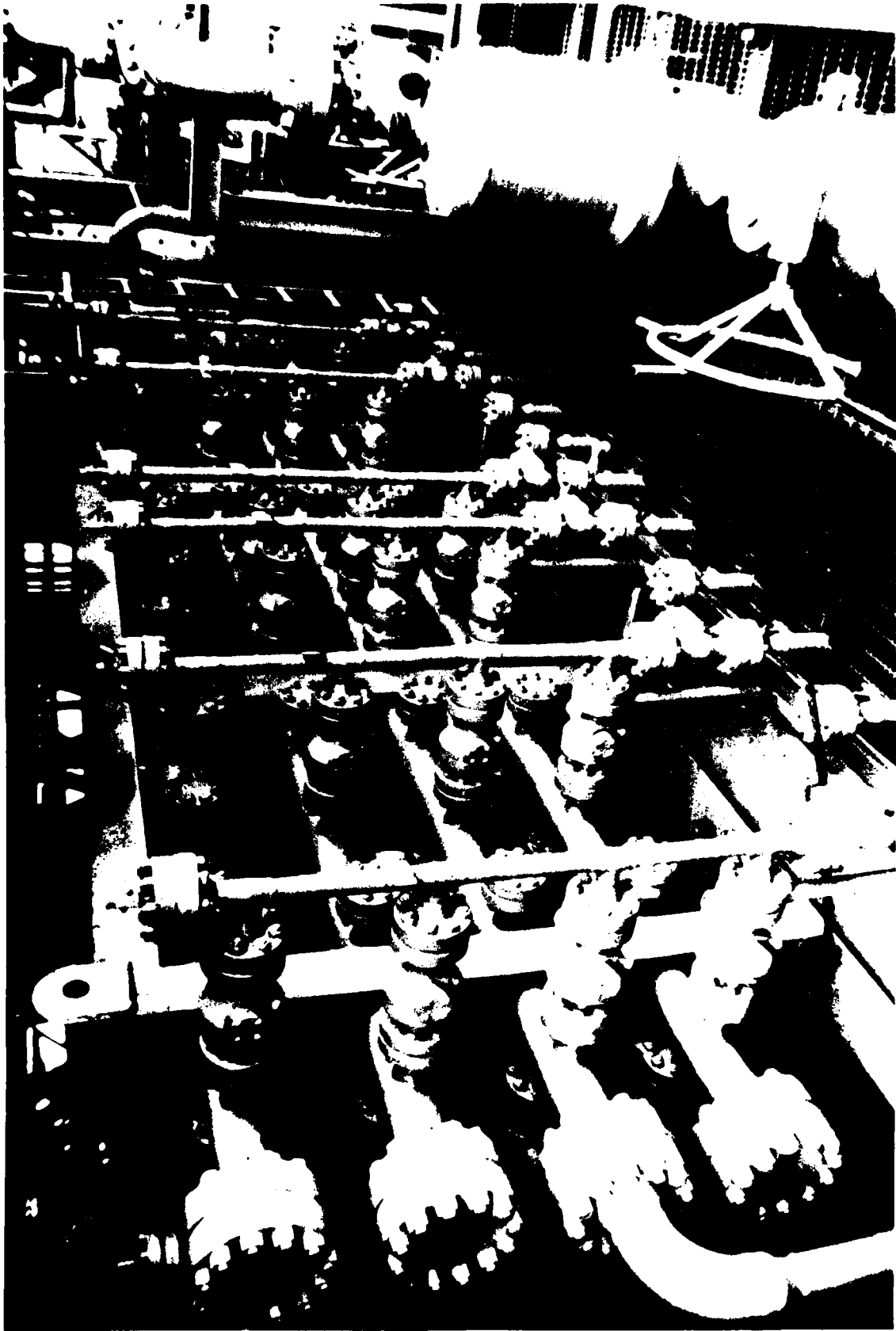


FIGURE D.2. MANIFOLDS

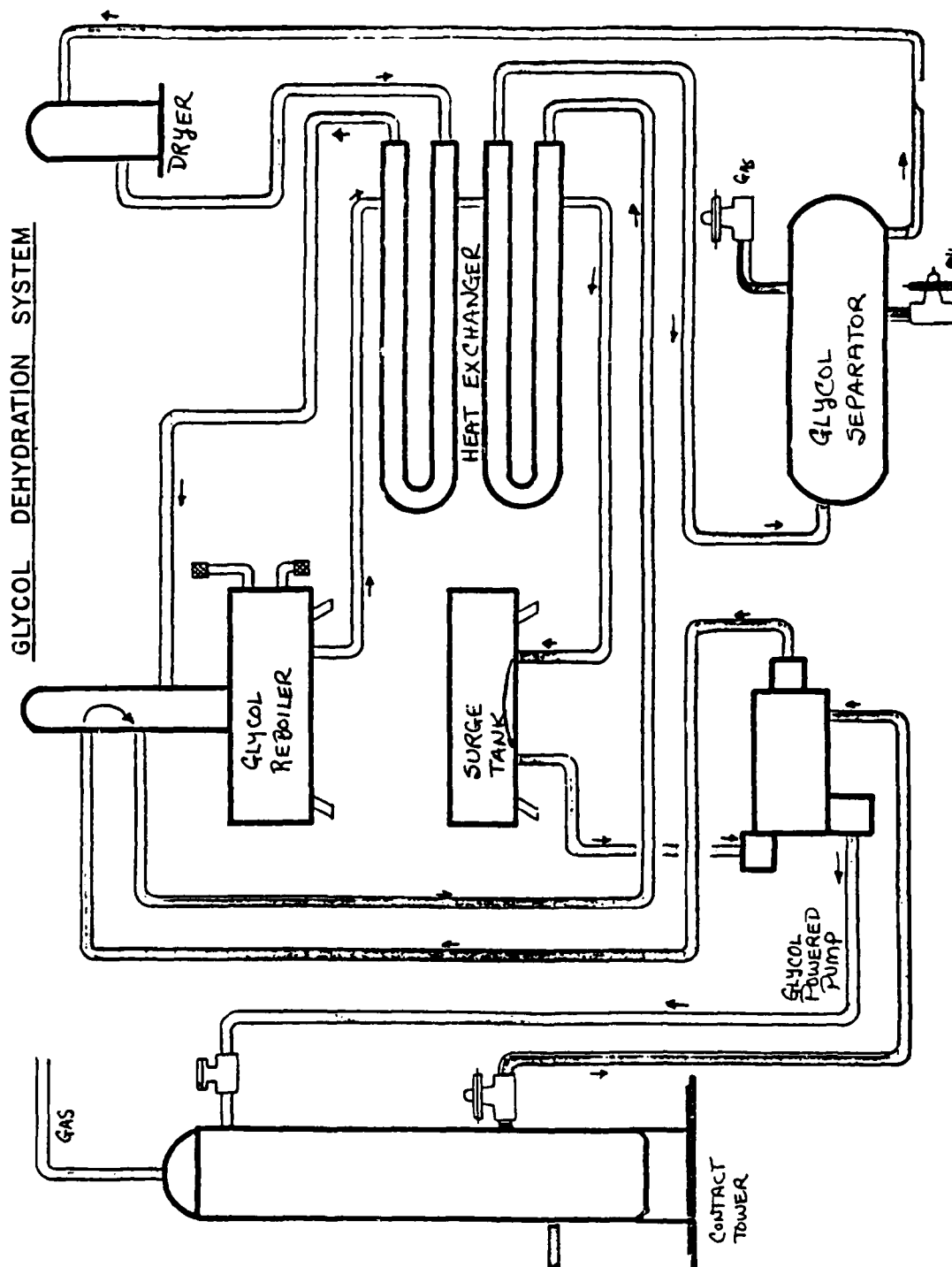


FIGURE D.3. GLYCOL DEHYDRATION SYSTEM

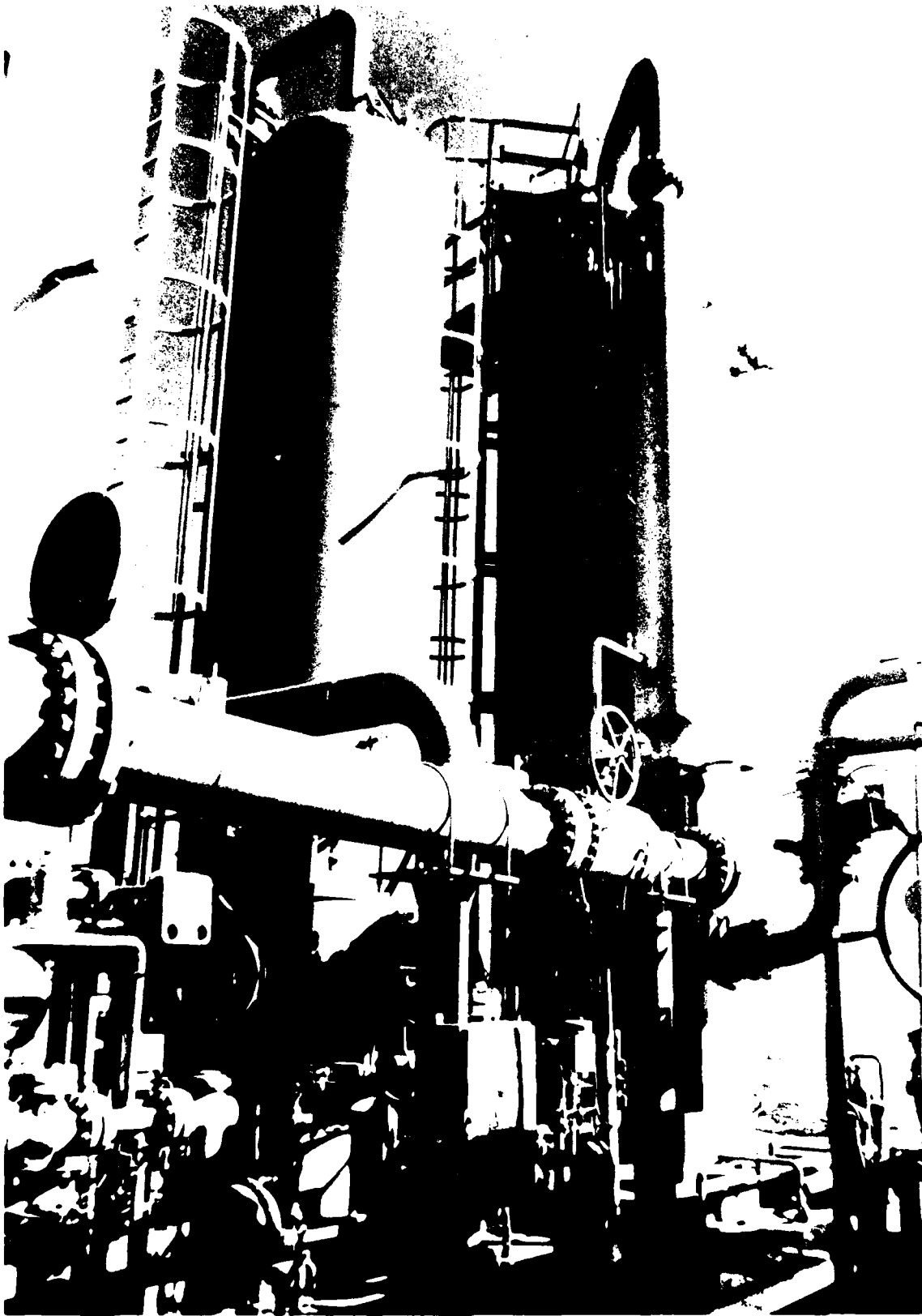


FIGURE D.4. GLYCOL CONTACT TOWER

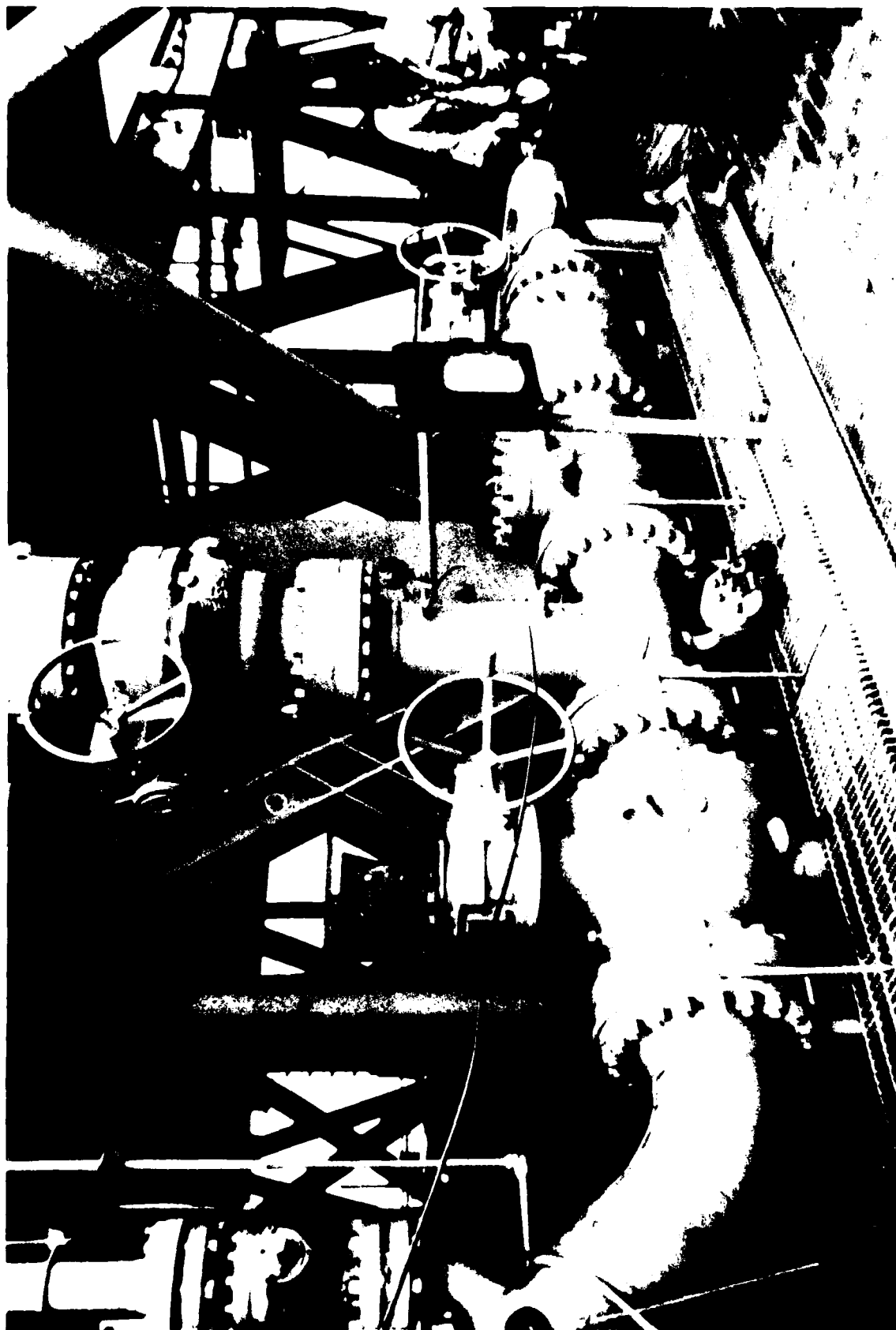


FIGURE D.5. PIG LAUNCH

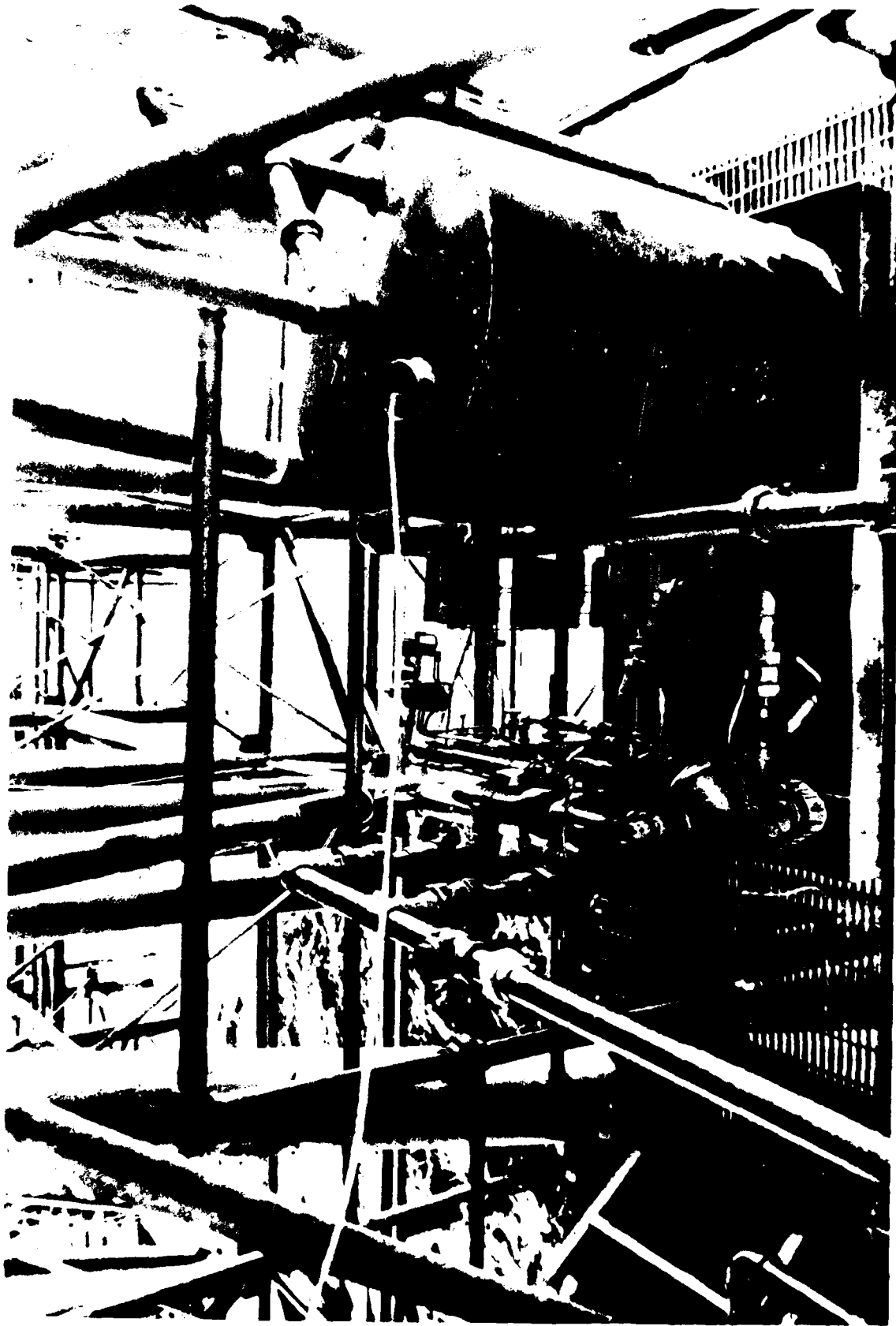


FIGURE D.6. SUNP AREA

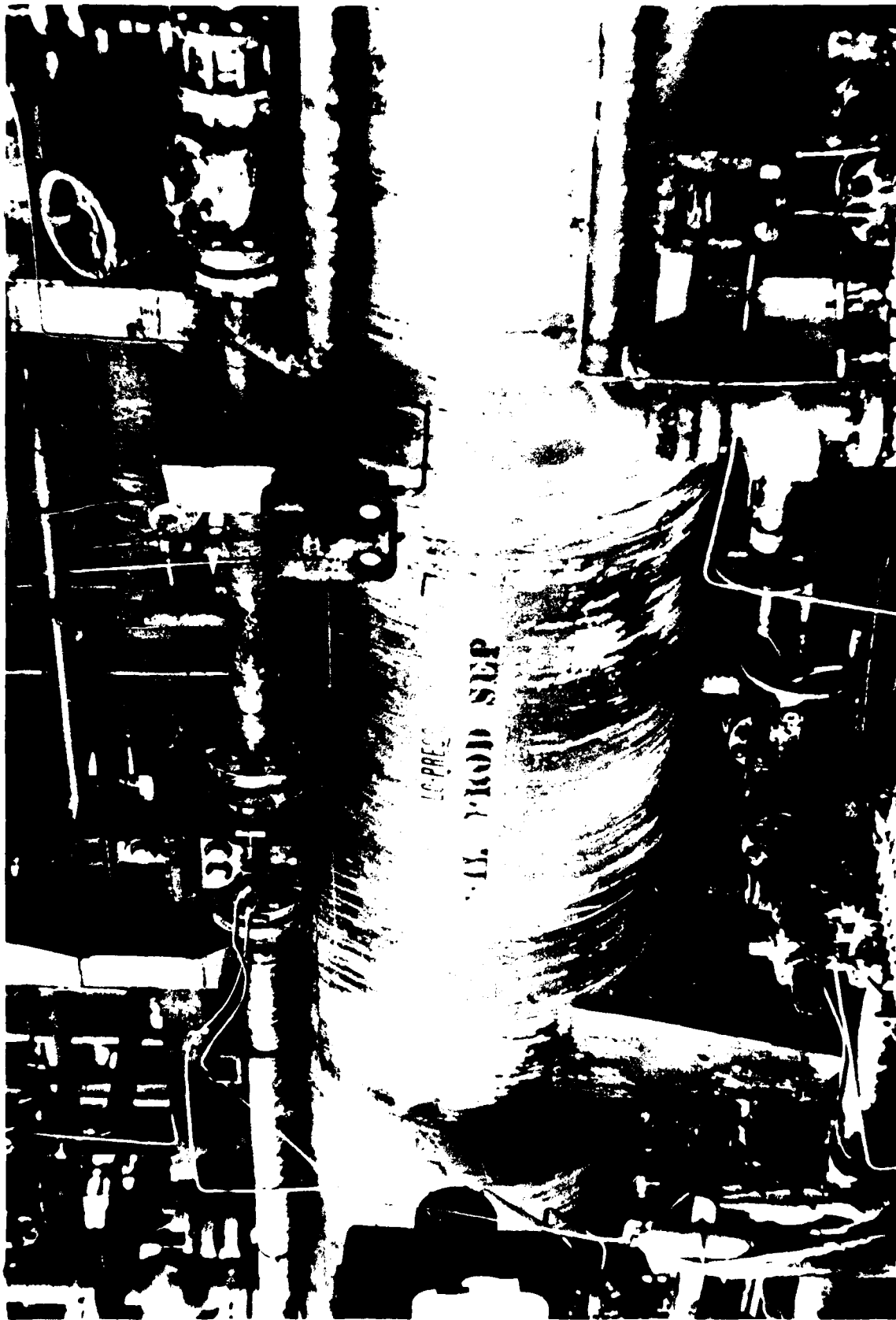


FIGURE D.7. TWO-PHASE SEPARATOR

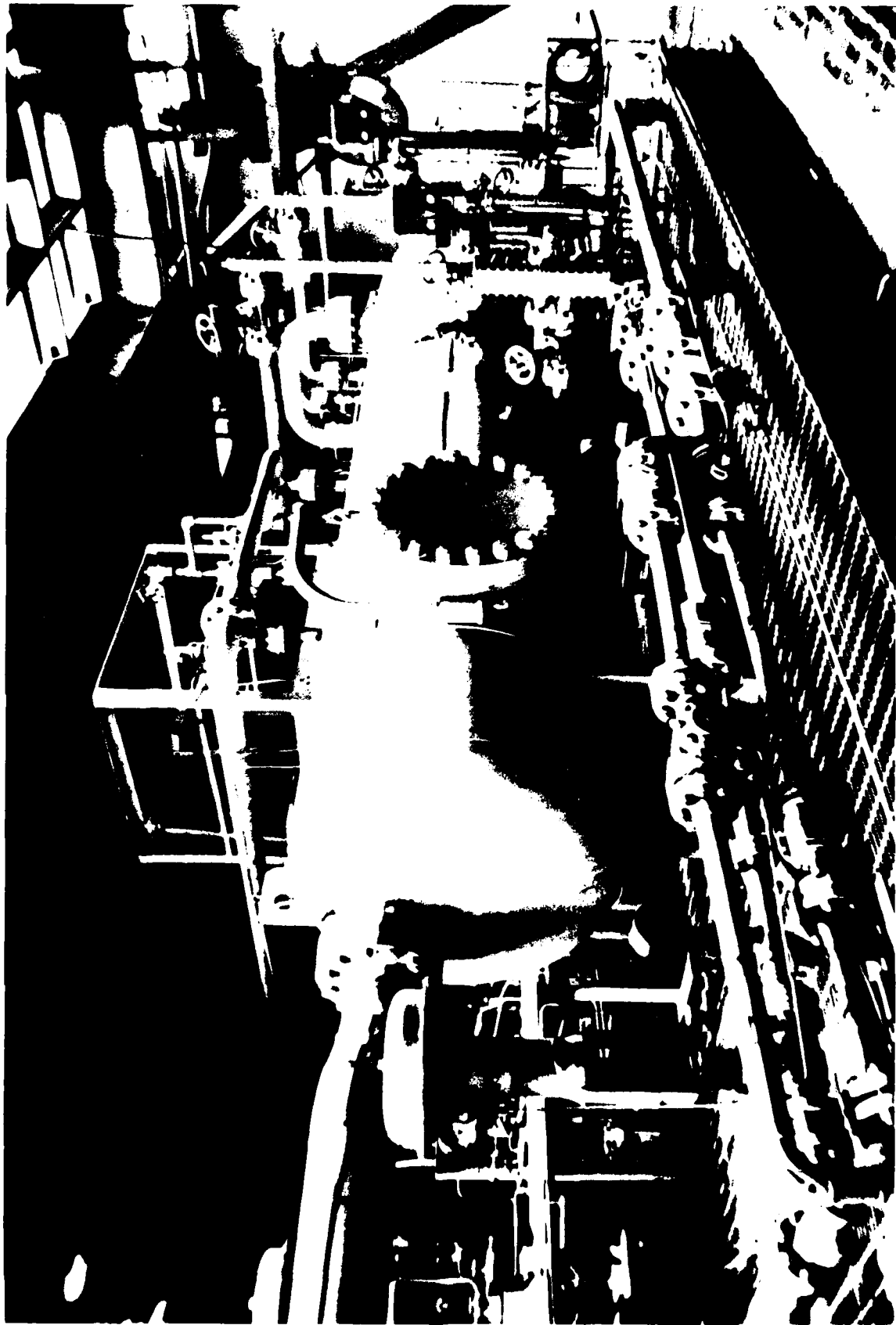


FIGURE D.8. TEST SEPARATOR



FIGURE D.9. FLOTATION CELL (SKIMMER)

APPENDIX E

DRILLING FLUIDS AND DRILLING FLUID ADDITIVES

DRILLING FLUID ADDITIVES

I. Viscosity-Reducing Agents

A. Tannins

1. Quebracho
2. Calcium Lignosulfonates
3. Sulfomethylated Tannin
 - a. Formaldehyde
 - b. Sodium Bisulfite
 - c. Caustic Soda
 - d. Quebracho
 - e. Chromium Chloride (optional)
 - f. Dry Chromium Salt (sodium chromate) (optional)

B. Polyphosphates

1. Sodium Acid Pyrophosphate (pH 4.2)
 - a. SAPP
 - b. $\text{Na}_2 \text{H}_2 \text{P}_2 \text{O}_7$
2. Sodium Tetrphosphate (pH 7.5)
 - a. $\text{Na}_6 \text{P}_4 \text{O}_{13}$
 - b. Most frequently used
3. Sodium "hexametaphosphate" (pH 7)
 - a. $(\text{NaPO}_3)_6$
 - b. Ratio of 1 Na_2O /1 P_2O_5
4. Organic Phosphates and Phosphonates
 - a. Phosphonic acid
 - b. Amino Phosphate

C. Lignitic Materials

1. Various names
 - a. Lignite
 - b. Leonardite
 - c. Mined Lignin
 - d. Brown Coal
 - e. Slack
2. Additives
 - a. Sodium Chromate
 - b. Caustic Soda
 - c. Potassium Salts
 - d. Zinc Sulfate

(Continued)

DRILLING FLUID ADDITIVES (CONTD)

D. Lignosulfonates

1. Composition

- a. 70 to 80% polysaccharides
- b. Remainder is lignin

2. Additives

- a. Lime
- b. Sodium Chromate
- c. Sodium Dichromate

3. Calcium Lignosulfonate

4. Chrome Lignosulfonate

5. Ferrochrome Lignosulfonate

E. Major Additives Used

1. Sodium Acid Pyrophosphate
2. Sodium meta or hexameta phosphate
3. Sodium Tetrphosphate
4. Caustic and Quebracho (sodium tannate)

II. Thickening Agents

- A. Asbestos
- B. Xanthan Gum

III. Viscosifiers

A. Bentonite

1. Sodium Bentonite
2. Calcium Bentonite

B. CMC (Sodium Carboxymethyl Cellulose)

C. Attapulgate Clays

1. Attapulgate
2. Sepiolite
3. Organophilic Clays

D. Sub-bentonites

IV. Surface Active Agents

- A. Emulsifiers
- B. De-emulsifiers
- C. Flocculants
- D. Deflocculants
- E. Anionic Group
 1. Carboxylates
 2. Sulfonates
 3. Sulfates
 4. Phosphates

(Continued)

DRILLING FLUID ADDITIVES (CONTD)

- F. Cationic Group
 - 1. Amine
 - 2. Quaternary
 - 3. Ammonium
 - 4. Other nitrogenous groups
- G. Nonionics
 - 1. Hydroxyl Groups
 - 2. Ethylene Oxide Chains
- H. Amphoteric
 - 1. Basic Group
 - 2. Acidic Group
- V. Weighting Materials
 - A. Barite (BaSO_4)
 - B. Lead Compounds
 - C. Iron Oxides
 - D. Siderite
 - 1. Ferrous Carbonate (FeCO_3)
 - 2. Iron Oxides
 - 3. Dolomite
 - 4. Calcite
 - 5. Quartz
 - E. Calcium Carbonate
 - 1. Limestone
 - 2. Oyster Shell
 - F. Galena (PbS)
- VI. Lost Circulation Materials
 - A. Flaky
 - 1. Cellophane
 - 2. Cotton Seed Hulls
 - 3. Mica
 - 4. Vermiculite
 - B. Granular
 - 1. Calcium Carbonate
 - 2. Coal
 - 3. Diatomaceous Earth
 - 4. Gilsonite
 - 5. Nut Shells
 - 6. Olive Pits
 - 7. Perlite
 - 8. Salt
 - 9. Synthetic Resins

(Continued)

DRILLING FLUID ADDITIVES (CONTD)

C. Fibrous

1. Asbestos
2. Bagasse
3. Flax Shives
4. Hog Hair
5. Leather
6. Mineral Wool
7. Paper
8. Rubber tires
9. Wood

VII. Lubricants

- A. Oils
- B. Graphite Powder
- C. Soaps
- D. Sodium Sulfonate Asphalt

VIII. Shale Control Inhibitors

- A. Gypsum
- B. Sodium Silicate
- C. Calcium Lignosulfonate
- D. Lime
- E. Salt
- F. Ammonium Acid Phosphate, $(\text{NH}_4)_2 \text{HPO}_4$

IX. Filtrate Reducers

- A. Asphalt Emulsion
- B. Guar Gum
- C. HEC (Hydroxyethyl cellulose)
- D. Bentonite clays
- E. CMC
- F. Pregelatinized Starch

X. Flocculants

- A. Salt
- B. Hydrated Lime
- C. Gypsum
- D. Sodium Tetraphosphates

XI. Alkalinity, pH Control

- A. Lime
- B. Caustic Soda
- C. Bicarbonate of Soda

XII. Bactericides

- A. Paraformaldehyde
- B. Caustic Soda
- C. Lime
- D. Starch

(Continued)

DRILLING FLUID ADDITIVES (CONTD)

XIII. Calcium Removers

- A. Caustic Soda
- B. Soda Ash
- C. Bicarbonate of Soda
- D. Polyphosphates

XIV. Corrosion Inhibitors

- A. Hydrated Lime
- B. Amine Salts
- C. Ammonium Sulfite

XV. Emulsifiers

- A. Modified Lignosulfonates
- B. Surface Active Agents
- C. Anionic Products
- D. Non-ionic Products

XVI. Defoamers

XVII. Foaming Agents

XVIII. Common Inorganic Chemicals

- A. Ammonium Acid Phosphate
 - 1. $(\text{NH}_4)_2 \text{HPO}_4$
 - 2. Shale Inhibitor
- B. Ammonium Bisulfite
 - 1. $\text{NH}_4 \text{HSO}_3$
 - 2. Reduce Corrosion of Iron
- C. Ammonium Sulfite
 - 1. $(\text{NH}_4)_2 \text{SO}_3 \cdot \text{H}_2\text{O}$
 - 2. Reduce Corrosion of Iron
- D. Calcium Bromide
 - 1. CaBr_2 , $\text{CaBr}_2 \cdot 6 \text{H}_2\text{O}$
 - 2. Preparation of dense salt solutions
- E. Calcium Chloride
 - 1. CaCl_2
 - 2. $\text{CaCl}_2 \cdot \text{H}_2\text{O}$
 - 3. $\text{CaCl}_2 \cdot 2 \text{H}_2\text{O}$
 - 4. $\text{CaCl}_2 \cdot 6 \text{H}_2\text{O}$
 - 5. Hole-stabilizing oil muds
 - 6. Calcium-treated muds
 - a. Completion
 - b. Workover
 - 7. Lower freezing point of water muds

(Continued)

DRILLING FLUID ADDITIVES (CONTD)

F. Calcium Hydroxide

1. Ca(OH)_2
2. Removal of soluble carbonates
3. In lime muds
4. In high-calcium-ion muds

G. Calcium Oxide

1. Ca O
2. In oil muds
 - a. Formation of calcium soaps
 - b. Removal of water

H. Calcium Sulfate

1. Ca SO_4 , Anhydrite
2. $\text{Ca SO}_4 \cdot 1/2 \text{ H}_2\text{O}$, plaster of Paris
3. $\text{Ca SO}_4 \cdot 2 \text{ H}_2\text{O}$, gypsum
4. Source of calcium ions in gyp muds

I. Chromic Chloride

1. $\text{CrCl}_3 \cdot 6 \text{ H}_2\text{O}$
2. Cross-linking xanthan gum

J. Chromium Potassium Sulfate

1. $\text{CrK (SO}_4)_2 \cdot 12 \text{ H}_2\text{O}$
2. Cross-linking xanthan gum

K. Copper Carbonate

1. $\text{CuCO}_3 \cdot \text{Cu(OH)}_2$
2. Sulfide scavenger

L. Magnesium Chloride

1. $\text{MgCl}_2 \cdot 6 \text{ H}_2\text{O}$
2. Avoid hole enlargement

M. Magnesium Hydroxide

1. Mg(OH)_2
2. Avoid hole enlargement

N. Magnesium Oxide

1. MgO
2. In acid-soluble completion fluids in conjunction with polymers
 - a. As buffer
 - b. As stabilizer

O. Potassium Carbonate

1. $\text{K}_2\text{CO}_3 \cdot 1-1/2 \text{ H}_2\text{O}$
2. Alkalizing agent in potassium treated muds

(Continued)

DRILLING FLUID ADDITIVES (CONTD)

- P. Potassium Chloride
1. KCl
 2. Source of potassium ions for potassium-polymer muds
- Q. Potassium Hydroxide
1. KOH
 2. Increase pH of potassium-treated muds
 3. Solubilize lignite
- R. Sodium Bicarbonate
1. Na HCO_3
 2. Counteract cement contamination of bentonite-water muds
- S. Sodium Carbonate
1. $\text{Na}_2 \text{CO}_3$
 2. Removal of soluble calcium salts from makeup waters and muds
- T. Sodium Chloride
1. NaCl
 2. Lower freezing point of mud
 3. Raise density
 4. Hole-stabilizing in oil muds
 5. Bridging agent in saturated solutions
 6. Completion and workover operations to saturate water before drilling rock salt
- U. Sodium Chromate
1. $\text{Na}_2 \text{CrO}_4$
 2. $\text{Na}_2 \text{CrO}_4 \cdot 10 \text{H}_2\text{O}$
 3. Increase thermal stability
 4. Inhibit corrosion in salty muds
- V. Sodium Dichromate
1. $\text{Na}_2 \text{Cr}_2 \text{O}_7 \cdot 2 \text{H}_2\text{O}$
 2. Increase thermal stability
 3. Inhibit corrosion in salty muds
- W. Sodium Hydroxide
1. Na OH
 2. Raise pH in water muds
 3. Solubilize lignite, lignosulfonate and tannin substances
 4. Counteract corrosion
 5. Neutralize hydrogen sulfide

(Continued)

DRILLING FLUID ADDITIVES (CONTD)

- X. Sodium Sulfite
 - 1. $\text{Na}_2 \text{SO}_3$
 - 2. Oxygen scavenger
- Y. Zinc Bromide
 - 1. Zn Br_2
 - 2. Prepare dense salt solutions
- Z. Zinc Carbonate, Basic Zinc Carbonate, Zinc Oxide, Zinc Hydroxide
 - 1. Zn CO_3 , $2 \text{ Zn CO}_3 \cdot 3 \text{ Zn(OH)}_2$, Zn O , Zn(OH)_2
 - 2. Remove hydrogen sulfide from mud
- AA. Zinc Chloride
 - 1. ZnCl_2
 - 2. Prepare dense salt solutions
- BB. Zinc Chromate
 - 1. Zn Cr O_4
 - 2. Corrosion inhibitor
- CC. Zinc Sulfate
 - 1. $\text{Zn SO}_4 \cdot \text{H}_2\text{O}$
 - 2. Corrosion inhibitor
- XIX. Cements
 - A. Ordinary type (O)
 - 1. Magnesium oxide (MgO)
 - 2. Sulfurtrioxide (SO_3)
 - 3. Tricalcium aluminate ($3 \text{ CaO} \cdot \text{Al}_2\text{O}_3$)
 - B. Moderate Sulfate-Resistant Type (MSR)
 - 1. Magnesium Oxide
 - 2. Sulfur Trioxide
 - 3. Tricalcium Silicate ($3 \text{ CaO} \cdot \text{Si O}_2$)
 - 4. Tricalcium Aluminate
 - C. High Sulfate-Resistant Type (HSR)
 - 1. Magnesium Oxide
 - 2. Sulfur Trioxide
 - 3. Tricalcium Silicate
 - 4. Tricalcium Aluminate
 - 5. Tetracalcium Aluminoferrite ($4 \text{ CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{Fe}_2\text{O}_3$)

(Continued)

DRILLING FLUID ADDITIVES (CONTD)

- XX. Additives to Oil-Well Cements
- A. Sodium Hydroxide (Na OH)
 - B. Sodium Carbonate ($\text{Na}_2 \text{CO}_3$)
 - C. Sodium Silicate ($\text{Na}_2 \text{SiO}_3$)
 - D. Sodium Hexameta Phosphate ($(\text{Na PO}_3)_6$)
 - E. Sodium Acid Pyro-Phosphate ($\text{Na}_2 \text{H}_2 \text{P}_2 \text{O}_7$)
 - F. Sodium Chloride (NaCl)
 - G. Starch ($(\text{C}_6 \text{H}_{10} \text{O}_5)_x$)
 - H. Sodium Carboxymethylcellulose (Na CMC)
 - I. Salts of Lignin Sulfonic Acid (Kembreck)
 - J. Tannin - Quebracho
 - K. Sodium Palconate
 - L. Tall-Oil Soap
 - M. Carbonox (Sub-bituminous material)

DRILLING FLUID REFERENCES

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APPENDIX F

COMPETITIVE MUD PRODUCTS

AD-A118 178

A CREW EXPOSURE STUDY VOLUME I OFFSHORE(U) SOUTHWEST
RESEARCH INST SAN ANTONIO TX ENGINEERING SCIENCES DIV
W J ASTLEFORD ET AL 15 MAR 82 82-6177-VOL-1

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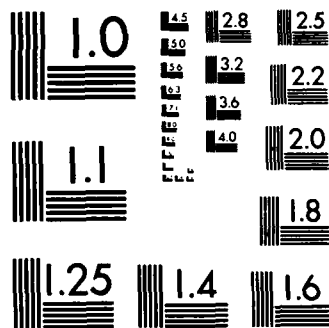
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

COMPETITIVE MUD PRODUCTS

DESCRIPTION	SUBSTANCE	MAGCOBAR	IMC	WEIGHTING AGENTS AND VISCOSIFIERS		MILCHEM	PRIMARY APPLICATION
				BAROID	MILCHEM		
Barite	Barium Sulfate.	Magcobar	Imcobar	*Baroid	Milbar		For increasing density to 20#/gal.
High density weight material	Pulverized Lead Ore.	Super-wate		Galena			For increasing density to 30#/gal.
Acid soluble high gravity weight material	High purity ground limestone.	Siderite			W.O.35		For increasing density to 18#/gal. with acid soluble material.
Acid soluble low gravity weight material		Lo-wate	Imcowate		W.O.30		For increasing density to 12.0#/gal with acid soluble material.
Bentonite		Magcogel	Imcogel	*Aqualgel	Milgel		Viscosifier and filtration control in water base muds.
Beneficiated Bentonite		Kwik Thik	ImcoHYB	Quickgel	Supercol		Quick viscosity in fresh water upper hole muds.
Attapulgate		Salt Gel	ImcoBrine Gel	Zeogel	Salt Water Gel		Viscosifiers in salt water muds.
Asbestos Fibers		Visbestos Visquik	ImcoSuper Best	Flosal	Flosal		Viscosifier for fresh or salt water muds.
Wet worked, low dust, pelletized, Asbestos Fibers		Super Visbestos	Super Visbestos	Super Visbestos	Super Visbestos		Viscosifier for fresh or salt water muds.
Bacterially produced Polymer	Long chain poly saccharide polymer produced by plant pathogenic bacteria.	Duovis	Imco XC	XC Polymer	XC Polymer		Viscosifier and fluid loss additive for low solids muds.

COMPETITIVE MUD PRODUCTS (CONTD)

<u>DESCRIPTION</u>	<u>SUBSTANCE</u>	<u>MACCOBAR</u>	<u>IMC</u>	<u>BAROID</u>	<u>MILCHEM</u>	<u>PRIMARY APPLICATION</u>
Guar Gum		Lo Loss		Lo Loss	Lo Loss	Viscosifier and fluid loss additive for low solids muds.
<u>DEFLOCCULANTS</u>						
Modified Lignosulfonate	Ferrochrome Lignosulfonate. *Spersene		VC-10 RD-111	*Q-Broxin	Uni-Cal	Deflocculant and protective colloid.
*Modified Tannin	Alkaline organic thinner.	Desco	Desco	Desco	Desco	Deflocculant and protective colloid.
Lignite		Tann-A-Thin	Imco Lig	*Carbonox	Ligco	Deflocculant, emulsifier and supplementary additive for fluid loss control.
Modified Lignite	Causticized lignite.	XP-20	ImcoThin	CC-16	Ligcon	Modified Lignite for supplementary use with Modified Lignosulfonate.
Potassium Lignite				K-Lig		For specific use as a thinner and fluid loss control agent in Potassium base systems.
Tannin Extract	Organic dispersing agent composed of 100% active materials.	MC-Quebracho	ImcoQT	Tannex	Mil-Quebracho	Thinner and protective colloid.
Hexametaphosphate	Sodium tetra phosphate, sodium tetra pyrophosphate.	Magcophos	Incophos	Barafos	Oilfos	Thinner for low pH fresh water muds and calcium sequestering agent.
Sodium Acid Pyrophosphate		SAPP	SAPP	SAPP	SAPP	Thinner for low pH fresh water muds and calcium sequestering agent.
Non-Ionic Surfactant		HME (Montello)	HME	HME	HME	Dispersant for gilsonite.

COMPETITIVE MUD PRODUCTS (CONTD)

<u>DESCRIPTION</u>	<u>SUBSTANCE</u>	<u>MAGCORBAR</u>	<u>IMC</u>	<u>FILTRATION CONTROL AGENTS</u>		<u>MILCHEM</u>	<u>PRIMARY APPLICATION</u>
				<u>PolyRX</u>	<u>Durenex</u>		
Organic Polymer	Water soluble, heat stable, synthetically formulated resin.	*Resinex				Chemtrol-X	Fluid loss control and high temperature stabilization of water base muds.
Pre-gelatinized Starch		My-Lo-Jel	ImcoLoid		Impermex	Milstarch	Controls fluid loss in SSW, fresh water, lime, and lignosulfonate muds.
Regular grade Sodium Carboxymethyl Cellulose		Magco-CMC (Regular)	Imco-CMC (Regular)		Cellex (Regular)	Milchem-CMC-MV	Fluid loss control and harite suspension in water base muds.
High Viscosity Sodium Carboxymethyl Cellulose		Magco-CMC (HI-Vis)	Imco-CMC (HI-Vis)		Cellex (HI-Vis)	Milchem-CMC-HV	Fluid loss control and barite suspension in water base muds.
Tech Grade Sodium Carboxymethyl Cellulose		Magco-CMC (Tech Grade)	Imco-CMC (Tech Grade)		Cellex (Tech Grade)	Milchem-CMC-TG	Fluid loss control in GYP, seawater, and fresh water muds.
Polyanionic Cellulose		Drispac	Imco Sure-Trol		*Drispac	Drispac	Fluid loss control additive and viscosifier in salt muds.
Sodium Polycrylate		Cypan WL-100 SPA (Amoco)	Cypan WL-100		Cypan WL-100	Cypan WL-100	Fluid loss control in calcium free low solids and non-dispersed muds.
Paraformaldehyde		My-Lo-Jel Preservative	Imco Preservaloid		Aldacide	Preservative	Prevents bacterial degradation of products.
Sodium Penta-chlorophenate		Dowcide G	Dowcide G		Dowcide G	Dowcide G	Bactericide used to prevent fermentation.

LUBRICANTS, DETERGENTS, EMULSIFIERS, SURFACTANTS

<u>Bit Lube</u>	<u>Imco EP Lube</u>	<u>EP Mud Lube</u>	<u>Lubri-Film</u>	<u>Used in water base muds to impart extreme pressure.</u>

COMPETITIVE MUD PRODUCTS (CONTD)

DESCRIPTION	SUBSTANCE	MAGCORBAR	IMC	BAROID	MILCHEM	PRIMARY APPLICATION
Sulfonated Residuum	Sodium asphalt sulfonate with minor amounts of asphalt phenalates, inorganic salts, and oxidized asphalt.	Soltex	Soltex	*Soltex	Soltex	Used in water base muds to lower downhole fluid loss and minimize heaving shale.
Water Dispersible Asphalts	Blown asphalt material in powdered form.	Stabilhole	Imcoholecoat	Baroid Asphalt	IPI (WD)	Lubricant and shale stabilizer for water base muds.
Detergent	Drilling Detergent (DD)		Imco MD	*ConDet	Milchem MD	Drilling mud detergent used to prevent balling, drop sand, emulsify oil, etc.
Graphite Lubricant	Flate Graphite Lube Kote		Graphite	Graphite	Mil-Graphhite	Mechanical lubricant for water base muds.
Non-ionic Surfactant	Surfak M		DMS	Aktaflo S	DMS	Primary surfactant for surfactant drilling fluids.
Non-ionic Emulsifier	Surfak E		DME	Aktaflo E	DME	Emulsifier for surfactant muds.
Blend of Anionic Surfactants	Salinex		Imco SMS	Seamul	Atlosol	Emulsifier for muds with salt contents between 15,000 and 150,000 NaCl.
Petroleum Sulfonated Emulsifier	Magconate			Trimulso		Emulsifier for use in fresh water, calcium free, low pH muds.
Diesel-Oil Substitute	Magcolube DOS-3 Drillaid 405 (Amoco)		Lubrikleen	Torn Trim	MilPlate 2 Lubri-Sal	Non-polluting lubricant for water base muds.
*Aluminum Stearate	Aluminum Stearate		Aluminum Stearate	Aluminum Stearate	Aluminum Stearate	Defoamer added in Diesel oil suspension for use in water base muds.
Sodium Alkyl Aryl Sulfonate	Defoamer A-40		ImcoDefoam			Defoamer for saturated salt muds.

DEFOAMERS, FLOCCULANTS

COMPETITIVE MUD PRODUCTS (CONTD)

<u>DESCRIPTION</u>	<u>SUBSTANCE</u>	<u>MAGCORAR</u>	<u>IMC</u>	<u>BAROLD</u>	<u>MILCHEM</u>	<u>PRIMARY APPLICATION</u>
Alcohol Base Defoamer	Two-ethyl hexanol commonly referred to as octyl alcohol.	Magconol	DFM	Surflo 300	W.O. Defoam	Defoamer for water base muds.
Flocculating Agent for Clay Solids	Organic, synthetic, water soluble polyelectrolyte.	Floxite Slec-Floc (Amoco)	Imco Floc	Barafloc	Separan	Flocculant used to drop solids where clear water is desirable for a drilling fluid.
Co-Polymer, Flocculant and Clay Extender	Polyvinyl acetate-maleic anhydride copolymer.	Ben-Ex VAMA (Amoco)	Imco Gellux	Ben-Ex	Ben-Ex	Increases yield of bentonite to form low solids drilling fluids.
Bentonite Extender Flocculant		Rapidrill Lo-Sol (Amoco)				Polymer for extending yield of bentonite and flocculating drill solids
<u>LOST CIRCULATION MATERIALS</u>						
Fibrous Material	Processed cane fiber.	Mud Fiber Magco Fiber	Imco Cedar Fiber	Fibertex	MilFiber	Filler and matting for material for lost circulation.
Nut Shells Fine		Nut Plug	Imco Plug	*Wall-Nut	Mil-Plug	Granular loss circulation material.
Nut Shells Medium		Nut Plug	Imco Plug	*Wall-Nut	Mil-Plug	Used with fibers and flake materials to regain circulation.
Nut Shells Coarse		Nut Plug	Imco Plug	*Wall-Nut	Mil-Plug	For use in fractured loss zones.
Ground Mica Fine		Magco-Mica	Imco-Mica	*MicaTex	Mil-Mica	Used for prevention of lost circulation.
Ground Mica Coarse		Magco-Mica	Imco-Mica	*MicaTex	Mil-Mica	Used for prevention of lost circulation.
Cellulose Flakes	Fragmented plastic foil.	Cell-O-Seal	Imco Flakes	Jel Flakes	MilFlake	Used in mixture of granular and fibrous materials.

COMPETITIVE MUD PRODUCTS (CONTD)

<u>DESCRIPTION</u>	<u>SUBSTANCE</u>	<u>MAGCOBAR</u>	<u>IMC</u>	<u>BAROID</u>	<u>MILCHEM</u>	<u>PRIMARY APPLICATION</u>
One sack combination of flake, fiber, and granular materials		Kwik-Seal	Kwik-Seal	Kwik-Seal	Kwik-Seal	Used to seal fractures or crevices.
Cottonseed Hulls		Cottonseed Hulls	Cottonseed Hulls	Cottonseed Hulls	Cottonseed Hulls	Used for all types of lost circulation problems.
Phenolic Flakes	Processed formica.	Pheno-Seal	Pheno-Seal	Pheno-Seal	Pheno-Seal	Used for all types of lost circulation problems.
Blended high fluid loss Diatomaceous earth. plugging material		DiaSeal M	DiaSeal M	DiaSeal M	DiaSeal M	One sack mixture for preparing soft plugs for severe lost circulation.
Low density inert solids for LC plugs	Diatomaceous earth.	DiaSeal-D	DiaSeal-D	DiaSeal-D	DiaSeal-D	Inert solid for high fluid loss soft plug squeeze preparations.
Shredded wood fiber		Chip Seal	ImcoCedar Fiber	Plug-Git	Mil-Cedar Plug	Used for general loss of returns.
Shredded Cellulose material		Dick's Mud Seal	Dick's Mud Seal	Dick's Mud Seal	Dick's Mud Seal	Shredded paper particles for general loss of returns.
<u>SPECIALTY PRODUCTS</u>						
Bentonite Extender		Ben-Ex	Imco-Gelex	Ben-Ex	Ben-Ex	Increases yield of bentonite to form low solids muds.
Foaming agent for brines and/or oil containing waters		Foamer 66			Amplifoam	Basic foamer for brine water Stiff-Foam.
Oil Soluble Surfactant		*Pipe Lax	Pipe Free	Not Free	Mil-Lax	Surfactant to mix with oil to free stuck pipe.
Oil soluble asphalt emulsion dispersible	Hydrocarbon Resins.	Wonderseal	ImcoHolecoat		IPI-WD	Used to seal micro-fractures in troublesome shales.

COMPETITIVE MUD PRODUCTS (CONTD)

DESCRIPTION	SUBSTANCE	MAGCOBAR	IMC	BAROID	MILCHEM	PRIMARY APPLICATION
Oil Dispersible asphalts		Pave-A-Hole	Imco Mud Oil	Baroid Asphalt	Carbo-Seal	Used to seal micro- fractures in trouble- some shales.
OIL BASE SYSTEMS AND ADDITIVES						
Basic package for Invert Emulsion system		V. rt011	Ken-X Kenol-S	Invermul	Carbo-Tec	Invert emulsion drilling mud and packer fluid.
Basic package for Oil Base system		*OilFaze	Ken- Supreme			Oil base drilling mud and packer fluid.
Organophilic Clay		VG-69	KenGel	*Gelstone	Carbo-Gel	Viscosifier and gelling agent for oil muds.
Liquid Organic Surfactant	Amber, viscous, petroleum- based liquid.	DV-33	Ken-X Conc #3	OMC	Surfcote	Oil wetting agent for water base solids.
Supplementary Emulsifier and Wetting Agent		SE-11		EZ-Mul	Carbo-Mul	Used for aiding oil wetting and emulsifica- tions.
Surfactant Cleaner		KU-1		Sluk-5	Mil-Emulsifier	Cleaning agent to cut oil and grime from metal parts and to wash up with on oil mud jobs.
High temperature FLC additive for oil muds		DV-22		*Duratone	Carbo-Frol	Controls HT-HP fluid loss of oil base systems.
DESCRIPTION		MAGCOBAR	CHAMPION	IMC	BAROID	PRIMARY APPLICATION
Amine Type Inhibitor	Chlorinated-phenol-type liquid.	Magco Inhi- bitor A-101	EPF-101	PT-102	Surf'n 833 Bioxide & pH	For fresh water packer muds

COMPETITIVE MUD PRODUCTS (CONTD)

DESCRIPTION	SUBSTANCE	MAGCOBAR	CHAMPION	IMC	BAROID	MILCHEM	PRIMARY APPLICATION
Drill Pipe Corrosion Inhibitor		Magcon Inhibitor A-202	DF-18	PT-102	Coat 415	Ami-Tec Aqua-Tec	Persistent film corrosion protection for drill pipe.
Water Soluble Inhibitor for Brines		Magcon Inhibitor A-303	Bactron 4 & pH		Coat-B-1400 Coat-122	Brine-Pac	For clear brines
Oxygen Scavengers		(a) OS-1 OS-1L + Magconol Defoamer (b) Zinc Chromate	(a) RDF109 2207 & pH + Bactron 4- R-142 (b) RDF 108		Coat 888 (dry) Coat 777 (liq) 4W-300 Defoamer Coat 113	Noxygen Noxygen-L 4W-0 Defoamer or LD 8 De-foamer	(a) Removes oxygen (b) Films pipe
Organic Phosphate Type Inhibitor		Si-1000	Cyptron		Surflo H-35		Tubular goods scale inhibitor
Sulfide Scavenger		Ironite Sponge Zinc Carbonate Zinc Chromate SCAV-730 (experimental)	2207+PH + Bactron 4	Crack-Chek Sulf-X	Zinc Oxide Ironite Sponge (also used as catalystizer for oxygen scavenger)	Mil-Gard	Used to treat H ₂ S intrusions.
Oil Base Casing Pack Fluids		Oil Faze & VertOil with Treated Asbestos		Ken-Pak	Invermul Csg Pack	Carbo Tec Invert Csg. Pack	Oil Base Annular Packer Fluid
Bactericide		Dowicide "C" My-Lo-Jel Preservative	Bactron 4		Aldacide & Dowicide "C"	Paraformaldehyde & Dowicide "C"	Control of bacterial growth.
DESCRIPTION		MAGCOBAR	IMC	BAROID	MILCHEM	PRIMARY APPLICATION	
COMMERCIAL CHROMATE							
* Sodium Chromate		Sodium Chromate	Sodium Chromate		Sodium Chromate		Used in water base muds to prevent high temperature gelation.

COMPETITIVE MUD PRODUCTS (CONTD)

DESCRIPTION	SUBSTANCE	MACCORBAR	IMC	BAROID	MILCHEM	PRIMARY APPLICATION
Sodium Hydroxide		Caustic Soda	Caustic Soda	*Caustic Soda	Caustic Soda	For pH control in water base muds.
*Sodium Carbonate		Soda Ash	Soda Ash	Soda Ash	Soda Ash	For treating out calcium sulfate in low pH muds.
*Sodium Bicarbonate		Sodium Bicarbonate	Sodium Bicarbonate	Sodium Bicarbonate	Sodium Bicarbonate	For treating out calcium sulfate or cement in high pH muds.
Barium Carbonate		Barium Carbonate	Barium Carbonate	Anhydrous	Barium Carbonate	For treating out calcium sulfate (pH should be above 10 for best results)
Calcium Sulfate		Gypsum	Gypsum	Gypsum	Gypsum	Sources of calcium for formulating gyp muds.
*Calcium Hydroxide		Lime	Lime	Lime	Lime	Source of calcium for formulating lime muds.
Sodium Chloride		Salt	Salt	Salt	Salt	For saturated salt muds and resistivity control.
Chrome Alum		Chrome Alum	Chrome Alum	Chrome Alum	Chrome Alum	For use in cross-linking XC-Polymer systems.
Cement (all types)		Cement	Cement	Cement	Cement	Bulk cement used in cementing operations.
*Calcium Chloride		Calcium Chloride	Calcium Chloride	Calcium Chloride	Calcium Chloride	Calcium salt used to control activity in oil muds.
Potassium Chloride (Mixture of Potash)		Potassium Chloride	Potassium Chloride	Potassium Chloride	Potassium Chloride	Potassium salt used in KCl systems.
Caustic Potash		Potassium Hydroxide	Potassium Hydroxide	Potassium Hydroxide	Potassium Hydroxide	Used to control pH in potassium base system.

COMPETITIVE MUD PRODUCTS (CONTD)

DESCRIPTION	SUBSTANCE	MAGCOBAR	IMC	BAROID	WORKOVER AND COMPLETION FLUID PRODUCTS		MILCHEM	PRIMARY APPLICATION
Polymer & Calcium Carbonate	Blend of hydroxyethylcellulose and calcium carbonate.	Polybrine	Vistex	W.O. 1	W.O. 20			Viscosifier and fluid loss control additive/brine fluids.
Graded-sized Calcium Carbonate		Mixical	Circotex		W.O. 30			Seepage loss control agent.
Polymer & sized Calcium Carbonate	Blend of hydroxyethylcellulose, lignosulfonate, and calcium carbonate.	Ceasstop	Hytex		W.O. 50			One package additive for viscous pill.
Alcohol base defoamer	Two-ethyl hexanol commonly, octyl alcohol.	Magconol	DFM	Surflo 300	W.O. Defoam			Defoamer.
Blend of lignosulfonate & special graded calcium carbonate		Ceascal						Used for seepage loss control.
Microbiocide	Powdered paraformaldehyde.			Aldacide				Prevent spoilage of organic colloids and prevent corrosion.
Viscosifier	Nonionic powdered hydroxyethylcellulose containing no CaCO_3 .			Baravis				For cleaning hole and improving purehole stability.
Brine Systems	Sodium Chloride Brine.	Magcobrine S.C.						Densities from 8.34 to 10.0 lb/gal.
	Potassium Chloride Brine.	Magcobrine P.C.						Densities to 9.7 lb/gal.
	Sodium Acetate Brine.	Magcobrine S.E.						Densities to 12.6 lb/gal.
	Calcium Chloride Brine.	Magcobrine C.C.						Densities 8.34 to 11.6 lb/gal.

COMPETITIVE MUD PRODUCTS (CONTD)

DESCRIPTION	SUBSTANCE	MAGCOBAR	IMC	BAROID	MILCHEM	PRIMARY APPLICATION
WORKOVER AND COMPLETION FLUID PRODUCTS						
Brine Systems (cont.)	Calcium Chloride/ calcium bromide brine solution ($\text{CaCl}_2/\text{CaBr}_2$).	Magobrine C.B.				Densities from 11.7 to 15.1 lb/gal.
	Zinc bromide/ calcium bromide brine solution ($\text{ZnBr}_2/\text{CaBr}_2$).	Magobrine Z.B.				Densities from 14.2 to 19.2 lb/gal.

Extracted from: Drilling Fluid Engineering Manual
Revised Edition, January 1977
Magobar Division, Dresser Industries, Inc.
pp. 20-29

Modified to include column entitled substance.

APPENDIX G

CHEMICAL PROPERTY DATA - DRILLING MATERIALS

KEY

1. An entry of N.A. in a particular column indicates that the information was not available.
2. For the TLV, the entry is in mppcf for solids and ppm for liquids. If the TLV is based on a single component of the substance, that component is listed.
3. The flash point test types are defined as follows:
 - COC - Cleveland Open Cup
ASTM-D92
 - PMCC - Pensky-Martens Closed Cup
ASTM-D93
 - SFCC - Setaflash Closed Cup
ASTM-D3278
 - TCC - Tag Closed Cup
ASTM-D56
4. It was not possible to quantify the solubility data found in the Material Safety Data Sheets. For this reason, the solubility is presented as it appeared on the MSDS forms.
5. The code for the safety equipment is:
 - R - Dust Respirator
 - G - Gloves
 - E - Eye Protection

CHEMICAL PROPERTY DATA - DRILLING MATERIALS

Chemical	Chemical Formula	Molecular Weight	Boiling Point, 1 ATM (°F)	Specific Gravity	TLV	Basis for TLV	Flash Point (°F/Test Type)	Normal State at Room Temperature	Solubility in Water	Recommended Safety Equipment		
Barite	BaSO ₄	233.43	N.A.	4.2	50 mppcf	<u>Weighting Agents and Viscosifiers</u>	None	Solid	Slight	R		
	N.A.		2.5	30 mppcf	None		Solid	N.A.	R			
Bentonite	Sodium Montmorillonite						<u>Deflocculants</u>					
			N.A.	1.20	30 mppcf		N.A.	Solid	100%	R		
Sperane	Chrome Lignosulfonate		N.A.	1.47	30 mppcf		N.A.	Solid	99%	R		
			N.A.	0.65	None Known		N.A.	Solid	Soluble	R, G, F		
RD-111			N.A.	1.50	N.A.		N.A.	Solid	Appreciable	R, G, F		
Q-Broxin	Petrochrome Lignosulfonate		N.A.	Unknown	0.3 mppcf		N.A.	Solid	Complete	R, G		
Uni-Cal			N.A.	1.70	50 mppcf		N.A.	Solid	N.A.	R		
Desco							<u>Dispersants</u>					
Carbonox												
SAPP	Na ₂ H ₂ P ₂ O ₇	221.95	N.A.	N.A.	N.A.		N.A.	Solid	N.A.			
Resinex			N.A.	1.35	30 mppcf	<u>Filtration Control Agents</u>	N.A.	Solid	100%	R, G, F		
			N.A.	1.60	N.A.		N.A.	Solid	Complete at 25°C			
			N.A.	1.04	15 mppcf		~ 600 COC	Solid	N.A.	R, F		
Black Magic SFT												
Imcro 106			N.A.	0.92	Not Established		<u>Lubricants, Detergents, Emulsifiers, Surfactants</u>	200 PHCC	Liquid	Insoluble	G, F	
			N.A.	0.98	45 mppcf			N.A.	Solid	75% at 90°C	R	
			21.7	1.20	N.A.			N.A.	Liquid	100%		
Solirox												
Com-Det												

CHEMICAL PROPERTY DATA - DRILLING MATERIALS (Cont'd)

Chemical	Chemical Formula	Molecular Weight	Boiling Point, 1 ATN (°F)	Specific Gravity	TLV (ppm)	Basis for TLV	Flash Point (°F/Test Type)	Normal State at Room Temperature	Solubility in Water	Recommended Safety Equipment
Magnolube			230	0.90	100 ppm	Amyl Alcohol	120 PMCC	Liquid	Appreciable	R, G, E
Torg-Trim			N.A.	0.92	400 ppm	Isopropyl Alcohol	67 TCC	Liquid	N.A.	R, G, E
Lubri-Sal			> 200	0.91	Not Established		>200 TCC	Liquid	Slight	R, G, E
Aluminum Stearate	$Al(OH)_n(CH_3(CH_2)_{16}COO)_3n$		N.A.	1.01	None Established		N.A.	Solid	Negligible	R, E
Wall-Nut Micatex			N.A.	N.A.	N.A.		N.A.	Solid	N.A.	R
Pipe Lax			176	0.963	2940 mppcf		122 PMCC	Liquid	Insoluble	R, G, E
Oilfaze			N.A.	N.A.	N.A.		385 PMCC	Solid	Insoluble	R
Geltone			N.A.	1.7	N.A.		N.A.	Solid	N.A.	R
Duratone			N.A.	1.8	50 mppcf		N.A.	Solid	Slight	R
Sodium Chromate	Na_2CrO_4	161.99	N.A.	N.A.	0.3 mppcf		N.A.	Solid	Readily	R, G,
Caustic Soda	$NaOH$	40.00	2534	2.13	6 mppcf		N.A.	Solid	100%	R, G, E
Soda Ash	Na_2CO_3	105.99	N.A.	2.53	N.A.		N.A.	Solid	50gm/100gm H_2O	R
Sodium Bicarbonate	$NaHCO_3$	84.11	N.A.	2.20	N.A.		Non-Flammable	Solid	9.6gm/100gm H_2O	R
Lime	$Ca(OH)_2$	74.10	5162	2.3-2.6	15 mppcf		N.A.	Solid	Negligible	R, G, E
Calcium Chloride	$CaCl_2$	110.99	3515	1.03	None		None	Solid	Very Soluble	

CHEMICAL PROPERTY DATA - DRILLING MATERIALS (Concl'd)

Chemical	Chemical Formula	Molecular Weight	Boiling Point, 1 ATM (°F)	Specific Gravity	TLV	Basis for TLV	Flash Point (°F/Test Type)	Normal State at Room Temperature	Solubility in Water	Recommended Safety Equipment
<u>Multipurpose Products</u>										
Tretolite BR-4099			N.A.	0.982	N.A.		92 PMCC	Liquid	Insoluble	G
Tretolite F-46			N.A.	1.042	N.A.		78 PMCC	Liquid	Insoluble	G,E
Tretolite RP-476			N.A.	1.004	N.A.		87 SFCC	Liquid	Insoluble	G,E
Tretolite RP-2327			N.A.	0.970	N.A.		90 PMCC	Liquid	Insoluble	G,E
<u>Corrosion Inhibitor</u>										
Cortron RN-97			N.A.	1.05	Undetermined		138 TCC	Liquid	Soluble	G,E
Kontrol K-152			N.A.	0.969	N.A.		90 PMCC	Liquid	Insoluble	G,E
Kontrol KG-6			N.A.	0.930	N.A.		100 SFCC	Liquid	Insoluble	G,E
Kontrol KP-123			N.A.	0.977	N.A.		94 PMCC	Liquid	Insoluble	G,E
Corexit 7755			325	0.912	100 ppm	Toluene	77 SFCC	Liquid	Dispersible	R,G,E
Corexit 7798			300	0.900	100 ppm	Toluene	100 SFCC	Liquid	Dispersible	R,G,E
Cortron HR-2293			180	0.900	Unknown		56 TCC	Liquid	Dispersible	R,G,E
<u>Thread Compounds</u>										
ZN 40			365	1.73	N.A.		200-400 CMC	Semisolid	Negligible	R,G,E
ZN 50			397	1.65	N.A.		200-400 CMC	Semisolid	Negligible	R,G,E
ZN 60			448	1.98	N.A.		200-400 CMC	Semisolid	Negligible	R,G,E
<u>Production Chemicals</u>										
Ethylene Glycol (Vapor)	$(CH_2OH)_2$	62.1	387.7	1.116	100 ppm		240 CMC	Liquid	Complete	E
Methanol	CH_3OH	32.04	147	0.792	200 ppm		54 TCC	Liquid	Complete	R,G,E

APPENDIX H

SUMMARY OF REGULATIONS

SUMMARY OF REGULATIONS

Agency	Regulation Code No./Title	Applicable Contents	Remarks
USCG	33CFR, Subchapter N, Parts 140-147, "Artificial Islands and Fixed Structures on the Outer Continental Shelf"	General provisions, inspections, operating requirements, and safety zones.	This subchapter is applicable to offshore structures, although none of the sections deal directly with personnel safety.
USCS	30CFR, Part 221, "Oil and Gas Operating Regulations"	Requirements for all lessees	Section 37 - Workmanlike operations Workmanlike operations are discussed, including health, safety, and removing of fire hazards.
	30CFR, Part 250, "Oil and Gas and Sulphur Operations in the Outer Continental Shelf"	Requirements for all lessees	Section 46 - Safe and workmanlike operations Workmanlike operations are discussed including health, safety, and removing of fire hazards.
		Contamination of air in surrounding areas	Section 57 - Air quality This section describes air quality standards as well as exemptions.
	30CFR, Part 251, "Geological and Geophysical Explorations of the Outer Continental Shelf"	Administrative authority and applicability	Section 3-5 - General requirements of notices and permits This section deals with the reporting of pollution, hydrocarbon releases, and environmental hazards.
		Disclosure of information	Section 14-1 - Disclosure of information and data to the public This section deals with the public announcement of a significant hydrocarbon occurrence or environmental hazard.
	Gulf of Mexico Outer Continental Shelf Orders	Order No. 7, pollution prevention and control	7.1.1 Liquid Disposal - A detailed list of drilling-mud components must be submitted as a part of the Application for Permit to Drill. The disposal of drilling mud is subject to the EPA's permitting procedures. All hydrocarbon-handling shall be designed and operated to prevent pollution.

SUMMARY OF REGULATIONS (CONCL'D)

Agency	Regulation Code No./Title	Applicable Contents	Remarks
USCS (Cont.)	Gulf of Mexico Outer Continental Shelf Orders (Cont.)	Order No. 7, pollution prevention and control	<p>7.1.2 <u>Solid Material Disposal</u> - The disposal of drill cuttings, sand, and other well solids containing oil is subject to the EPA's permitting procedures. Disposal of equipment into the ocean is prohibited except under emergency conditions.</p> <p>7.2.2 <u>Pollution Inspections</u> - Manned and unattended facilities shall be inspected daily to determine if pollution is occurring.</p>
		Order No. 5, production safety systems	<p>5.1.9 <u>Fire and Gas Detection System</u> - Fire sensors shall be used in all enclosed high-hazard areas. Gas sensors shall be used in all inadequately ventilated, enclosed, high-hazard areas. A fuel gas odorant or an automatic gas-detection and alarm system are required in enclosed, continuously manned areas in the facility.</p> <p>5.1.10 <u>Electrical Equipment</u> - All electrical generators, motors, and lighting systems shall be installed, protected, and maintained in accordance with the National Electrical Code.</p>

APPENDIX 1

DERMATOLOGICAL EFFECTS OF DRILLING FLUIDS

GLOSSARY OF TABLE HEADINGS

Primary Irritant: A substance that will cause skin damage or dermatitis at the site of contact if permitted to act for a sufficient length of time.

Corrosive or Ulcer Hazard: A substance that burns, or destructively attacks living tissue, most notably the skin and eyes.

Allergic Sensitizer: A substance that has the ability to cause sensitization from various degrees of exposure. After becoming sensitized to the substance, a person may exhibit allergic reactions on subsequent exposure.

Photosensitizer: A substance that causes sensitization of skin only in the presence of light (usually ultraviolet light or sunlight).

Acne-Like Diseases: A substance that causes an acne-form condition or folliculitis.

Carcinogenic: A substance with any property or characteristic to produce cancer.

Systemic by Skin Absorption: A substance that is absorbed through intact skin, and which may cause systemic effects after absorption.

Eye Hazard: A substance that is injurious to the eyes on contact.

OCCUPATIONAL EXPOSURE SKIN HAZARD RATING CODE

The ratings used in the table indicate the relative hazard as follows:

1 = slight effects

- a. acute local: materials which on single exposures lasting seconds, minutes, or hours cause only slight effects on the skin or mucous membranes regardless of the extent of the exposure.
- b. chronic local: materials which on continuous or repeated exposures extending over periods of days, months, or years cause only slight and usually reversible harm to the skin or mucous membranes. The degree of exposure may be moderate or small.

2 = moderate effect

- a. acute local: materials which on single exposure lasting seconds, minutes, or hours cause moderate effects on the skin or mucous membranes. These effects may be the result of intense exposure for a matter of seconds or moderate exposure for a matter of hours.
- b. chronic local: materials which on continuous or repeated exposures extending over periods of days, months, or years, cause moderate harm to the skin or mucous membranes.

3 = severe effect

- a. acute local: materials which on single exposure lasting seconds or minutes cause destruction of skin or mucous membranes of sufficient severity to threaten life or to cause permanent physical impairment or disfigurement.
- b. chronic local: materials which on continuous or repeated exposures extending over periods of days, months, or years can cause injury to skin or mucous membranes of sufficient severity to threaten life or cause permanent impairment, disfigurement, or irreversible change.

TABLE I

Chemical Name	Corrosive or Ulcer Hazard	Primary Irritant	Allergic Sensitizer	Photosensitizer	Acne-like Diseases	Carcinogenic	Systemic by Skin Absorption	Eyes	Comments
Aldicide		X	X					X	contains paraformaldehyde.
ammonium acid phosphate		mild						mild	
ammonium bisulfite		mild							
ammonium sulfite		mild							
asbestos		X							mechanical irritant. Granulomatous dermatitis
asphalt, powdered		al 2 cl 2							
bagasse		al 2	al 2						May be stabilized with para- formaldehyde (see which)
barium carbonate	X	al 1 cl 1						X	
calcium hydroxide	X							severe	
calcium lignosulfonates			X						
calcium oxide (lime)	X							severe	
caustic soda (sodium hydroxide)	X							severe	
cedar wood			cl 1					X	
cement		mild						X	see chromium compounds, p. 1-7, and Portland cement
chrome alum	X							severe	see chromium compounds, p. 1-7
chrome lignosulphonate			X					X	see chromium compounds, p. 1-7
chromic potassium sulfate			X					severe	see chromium compounds, p. 1-7
copper carbonate		X						severe	

TABLE I (CONTD)

Chemical name	Corrosive or Ulcer Hazard	Primary Irritant	Allergic Sensitizer	Photosensitizer	Acne-Like Diseases	Carcinogenic	Systemic by Skin Absorption	Eyes	Comments
chromium chloride	X	al 3 cl 3						severe	see chromium compounds ¹ , p. 1-7
detergents		mild						X	dehydrating
Dowicide G		X	X		X			severe	see sodium pentachlorophenate ² , p. 1-7
formaldehyde		al 3 cl 1						severe	
Gilsonite		al 2 cl 2	cl 2	X					
hog hair			X						
hydrated lime (calcium hydroxide)	X							severe	
iron oxides		al 1						X	mechanical
leather			al 1 cl 1					X	see chromium compounds, p. 1-7 and sodium pentachlorophenate ²
lead compounds								X	systemic by ingestion from poor personal hygiene
magnesium hydroxide	X								
mica		X							mechanical
mineral wool		X							mechanical
modified lignosulfonates			X						
paraformaldehyde		al 3 cl 1	al 1 cl 1					severe	same as formaldehyde, but slower onset of effects
Portland cement		al 2 cl 2	al 1 cl 1					X	see chromium compounds ¹ , p. 1-7
potassium carbonate (potash)	X							X	
potassium hydroxide	X	al 3 cl 1						severe	

TABLE I (CONTD)

Chemical name	Corrosive or Ulcer Hazard	Primary Irritant	Allergic Sensitizer	Photosensitizer	Acne-Like Diseases	Carcinogenic	Systemic by Skin Absorption	Eyes	Comments
soaps		mild						X	degree of irritation depends on alkalinity
sodium alkyl aryl sulfonate		mild							Requires prolonged contact
sodium bisulfite								X	
sodium bromide		mild						severe	
sodium carbonate	X	al 2 cl 1						severe	
sodium chromate (dry)	X	al 3 cl 3	X			X		severe	see chromium compounds ¹ , p. 1-7
sodium dichromate	X					X		severe	see chromium compounds ¹ , p. 1-7
sodium hydroxide	X	al 3 cl 2						severe	
sodium pentachlorophenolate		al 3 cl 2			X		X	severe	see sodium pentachlorophenolate ² , p. 1-7
sodium silicate	X							severe	
solvents		X	X					X	
starch dust			X					X	
sulfur trioxide	X	al 3 cl 2						severe	
surfactants		X						severe	
tall-oil		al 1 cl 1						X	
tricalcium silicate									see Portland cement
zinc chloride	X							severe	ulcers of nasal septum

[illegible]

SYMBOLS: (For detailed explanation, see below)

al = acute local cl = chronic local 1 = slight effect 2 = moderate effect 3 = severe effect

Note: Materials classified as "corrosive or ulcer hazard" are also primary irritants and severe eye hazards.

¹Chromium compounds: The chromates (Cr^{6+}) are recognized carcinogens of the nasal cavity and other internal sites. They are highly corrosive and irritating. Chromous (Cr^{2+}) and chromic (Cr^{3+}) salts are less hazardous than the hexavalent (Cr^{6+}) compounds. Cement and Portland cement may be alkaline to a harmful degree, they often contain chromium, which can produce "cement sensitization," causing dermatitis and green tattoo areas (from Cr^{3+}). Chrome dermatitis does not necessarily accompany chrome ulcers. Perforations of the nasal system may occur under continuous dust exposure to chromium compounds. Leather may be tanned with chromium compounds which are allergenic.

²Sodium pentachlorophenate: In solution, it is absorbed through the skin. Target systemic organs are the liver and kidneys. Dowicide G contains sodium pentachlorophenate, and other Dowicides generally contain pentachlorophenol. Dowicides are used as bacteriocides and preservatives. Leather, wood, paper, and cellulose may be preserved with these compounds. Sodium pentachlorophenate is considered as hazardous as the neat pentachlorophenol.

TABLE II
No Effect From Skin Contact

aluminum stearate
bicarbonate of soda
brown coal
calcite
calcium bromide
calcium chloride
calcium sulfate
cellophane
coal
diatomaceous earth
dolomite
flax shives¹
galena
graphite powder
gypsum
inorganic lead compounds²
lead ore (pulverized)²
lignite
limestone
magnesium chloride
magnesium oxide
paper¹
phenolic flakes (processed formica)
polyanionic cellulose
quartz
rubber tires
salt (sodium chloride)
salts of lignin sulfonic acid
sodium acid pyrophosphate
sodium bentonite
sodium bicarbonate
sodium chloride (salt)
sodium palconate
sodium polycrylate
sodium sulfonate asphalt
sodium tetraphosphates
subbentonites
tetracalcium aluminate
tetracalcium aluminoferrite
vermiculite
zinc carbonate
zinc hydroxide
zinc oxide

¹ May be treated with preservatives; see sodium pentachlorophenate, p. I-7.

² Systemic effects by ingestion from poor personal hygiene.

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APPENDIX J

CHEMICAL PROPERTY DATA -
GASES AND HYDROCARBON VAPORS

CHEMICAL PROPERTY DATA - GASES AND HYDROCARBON VAPORS

Compound	Molecular Weight	TOXICOLOGICAL PROPERTIES			FLAMMABILITY PROPERTIES **			
		TLV-TWA* (ppm)	TLV-STEL* (ppm/min)	Odor Threshold** (ppm)	Flash Point °F/Test Type	LEL (% Vol)	UEL (% Vol)	
Benzene	78.11	25	$\frac{25}{15}$	4.68	12/c.c.	1.3	7.9	
Butane	58.12	800	Not Available	6.16	-100/(est)	1.8	8.4	
Carbon Dioxide	44.0	5000	$\frac{15,000}{15}$	N/A	N/A	N/A	N/A	
Cyclohexane	84.16	300	$\frac{375}{15}$	Not Available	-4/c.c.	1.33	8.35	
Ethane	30.07	N/A	N/A	899	-211	2.9	13.0	
n-Heptane	100.21	400	$\frac{500}{15}$	220	25/c.c.	1.0	7.0	
n-Hexane	86.17	50†	$\frac{125}{15}$	Not Available	-7/c.c.	1.2	7.7	
Hydrogen Sulfide	34.08	10	$\frac{15}{15}$	0.0047	N/A	4.3	45	
Methane	16.04	N/A	Not Available	200	N/A	5.0	12.0	
Methyl Cyclopentane	84.2	Not Available	$\frac{300}{60}$	Not Available	0/c.c.	1.1	8.7	
Nitrogen	28.0	Non-Toxic	N/A	N/A	N/A	N/A	N/A	
Pentane	72.15	600	$\frac{750}{15}$	10	-57/c.c.	1.4	8.3	
Propane	44.09	1000	Not Available	5,000 - 20,000	-156/c.c.	2.1	9.5	
Toluene	92.14	100	$\frac{150}{15}$	0.17	40/c.c.	1.27	7.0	

* From Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment with Intended Changes for 1981, ACGIH.

** From Chemical Hazards Response Information System (CHRIS), Volume II.

† TLV-TWA = 500 ppm for other isomers of hexane. ACGIH notice of intended changes, 1981.

APPENDIX K

INTERMEDIATE TRIP REPORTS

- o K.1 OFFSHORE PRODUCTION FACILITIES
- o K.2 OFFSHORE DRILLING FACILITIES

K.1 OFFSHORE PRODUCTION FACILITIES

From 8/26/81 to 8/28/81, two SWRI engineers performed an observation of production activities on an offshore platform owned and operated by company G. The observation was conducted on platform A in a field of four production platforms, A, B, C, and D. Platform A provides the living quarters and galley facilities for the field.

Platform A has one flowing well producing 40 bbls/day of oil and 185,000 cubic feet/day of natural gas. There are eleven oil and gas pipelines running to and from platform A. This platform has facilities for oil and gas separation and processes 1400 barrels/day of oil and 16,000,000 cubic feet/day of natural gas.

Table K.1 shows the crew complement for this field. These crew members are stationed at platform A, but will travel by crewboat to work on other platforms in the field as required. The wireline and workover rig crews were working on other platforms, but ate and slept at platform A.

There are actually two platforms joined by a walkway that make up platform A. Figure K.1 shows the production platform which has all of the production, separation and pipeline transfer equipment on it. Figure K.2 shows the adjacent platform that contains the galley, the sleeping quarters, office space for the field superintendent and maintenance foreman, a changing room, and a meeting/recreation room, and the heliport.

Our first activity was to carry out a walk-through survey of the facilities on the production platform to locate and identify contaminant emission sources. A Century Organic Vapor Analyzer Model 108 was used in its total hydrocarbon mode during the emission survey. This instrument indicates the concentration of organic gases and vapors as an equivalent concentration of methane over a logarithmic scale ranging from 1 ppm to 10,000 ppm. If an emission source gives a reading that is off-scale, it is necessary to dilute a sample of the contaminant gas stream with a known volume of air to obtain a true measurement of concentration. Since the purpose of the walk-through survey was to identify contaminant emission sources rapidly, a reading of >10,000 ppm was recorded when a reading was off-scale.

The results of the emission source survey are shown in Table K.2. The well heads, the oil and gas pipelines to and from other platforms, and two sump tanks are located on the cellar or lower deck of the platform shown in Figure K.3. This deck is open to the air and wind which prevents the accumulation of gases and vapors from emission sources.

Several sources for low flowrate, fugitive emissions were found at flanges and on valves in the oil and gas transfer piping on the cellar deck. Fugitive emissions were also found from sumps, instrument gas line connections, level controller, and flow rate control valves. Figure K.4 shows the OVA indicating a total hydrocarbon concentration of about 1000

TABLE K.1 CREW COMPLEMENT ON OFFSHORE PRODUCTION PLATFORM

Title	No.	Description
Field Superintendent	1	
Maintenance Foreman	1	
Maintenance Specialists	5	They perform loading and unloading of boats, installation of new equipment, valve and piping repair, housekeeping, painting, new construction.
Operators	2	They are in charge of production and production equipment. They do well testing, treating, maintain pumps and generators, pig pipelines and perform preventive maintenance.
Senior Technicians		
- Mechanical	1	He takes care of cranes, compressors, etc., and performs preventive maintenance.
- Electrical	1	He takes care of instrumentation and performs safety device tests required by USGS. Calibrates production meters every month and performs preventive maintenance.
Galley Personnel		
- Cook	1	Contract worker.
- Galley hand	1	Contract worker.
Wireline Crew	2	Contract personnel
Workover Rig Crew		
- Tool pusher	1	Contract personnel
- Night man	1	" "
- Derrick crew	4	" "

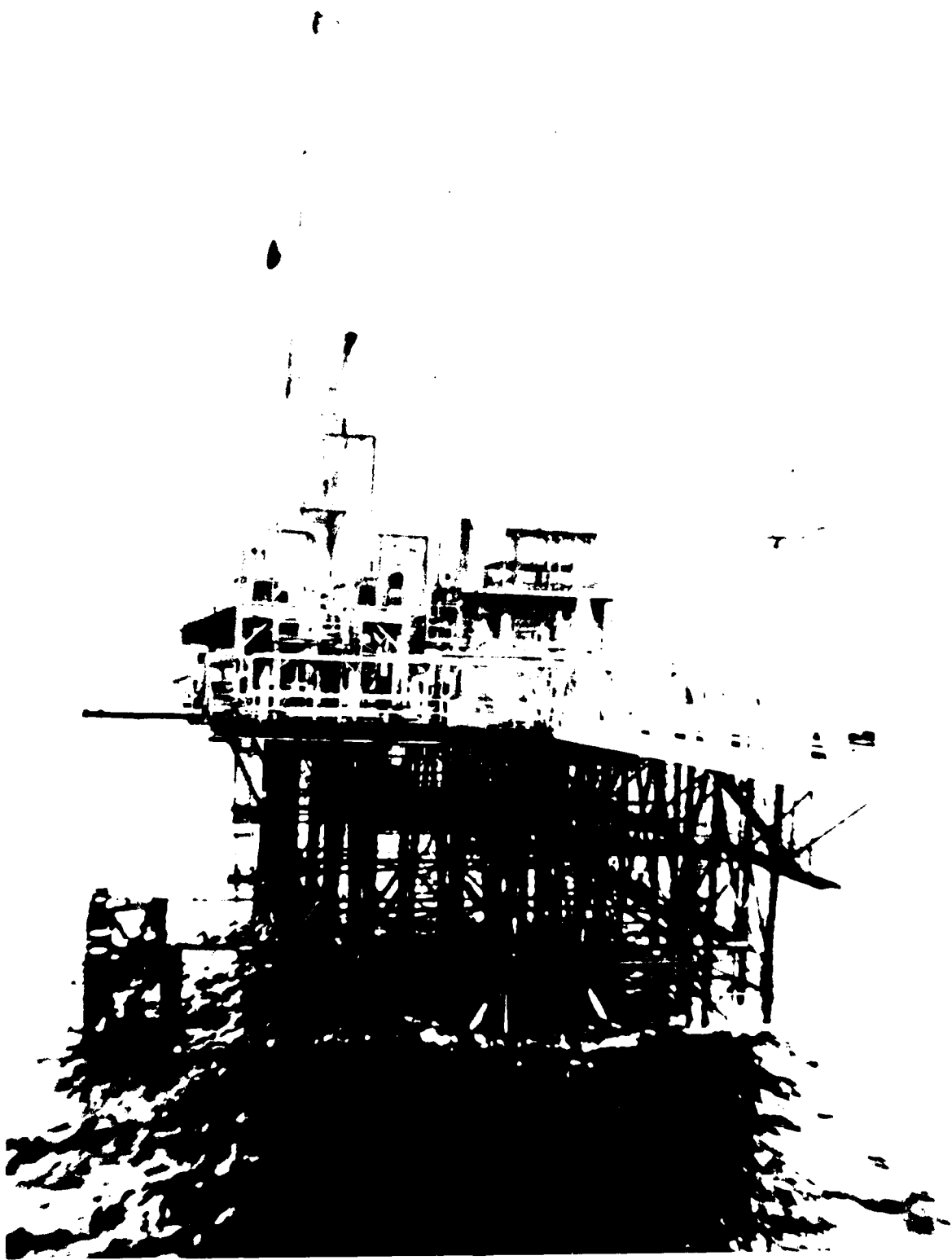


FIGURE K.1. PRODUCTION PLATFORM A, COMPANY G



FIGURE K.2. LIVING QUARTERS, GALLEY AND OFFICES FOR PLATFORM A

TABLE K.2

GAS CONCENTRATIONS ON OFFSHORE PLATFORMS

COMPANY:	G
PLATFORM:	A
DATE:	8/26/81
<u>AREA/EQUIPMENT</u>	
<u>GAS CONCENTRATION</u> <u>ppm (total as methane)</u>	
<u>Cellar (Lower) Deck</u>	
o Gas lift pipeline to platform D, background concentration	8 ppm
o Oil pipeline from platform D, background concentration	8 ppm
o Oil and gas pipeline from platform B, - leakage at flange	20 to 100 ppm, max. 150 ppm
- 1.2m downwind of flange	10 to 30 ppm
- stem of valve on pipeline	>10,000 ppm
o Oil and gas pipeline header	8 to 20 ppm
o 65-barrel sump tank	
- from flange and threaded joint	1000 to 2000 ppm
- interior of level controller (Figure K.5)	700 ppm
- 2m downwind of tank	700 to 1000 ppm
o Well Head, A-7	
- background concentration	40 to 90 ppm
- leakage at flange	max. 200 ppm
o Fuel gas instrument lines	200 to 700 ppm
o Sump tank	
- background concentration	70 to 100 ppm
- at top of atmospheric vent	70 ppm
- near pipe union	200 to 300 ppm
- 1 m above grating	300 to 400 ppm

TABLE K.2 (CONTD)

GAS CONCENTRATIONS ON OFFSHORE PLATFORMS

COMPANY: G
 PLATFORM: A
 DATE: 8/26/81

<u>AREA/EQUIPMENT</u>	<u>GAS CONCENTRATION ppm (total as methane)</u>
o High Pressure Oil Pipeline Header	< 30 ppm
o Low Pressure Oil Pipeline Header to Platform C	< 30 ppm
<u>Main (Upper) Deck</u>	
o On stairway from cellar deck	
- at floor level of main deck	30 to 50 ppm
- at breathing height above main deck	50 to 70 ppm
o Around waste drum and container bin	
- outside of bin	40 to 200 ppm
- discarded container	8000 ppm
o Dead oil transfer pump (see Figure K.7)	
- next to pump driveshaft at speed transducer	2000 to 4000 ppm
- around transfer pump	150 to 300 ppm
o Fuel gas engine for dead oil transfer pump (see Figure K.8)	
- around drive shaft	200 to 300 ppm
- around lubricator	500 to 1500 ppm
- from oily residue on drip tray	1000 to 2000 ppm
o Control panel for pump and engine	
- leak of instrument gas from panel at #2 discharge pressure meter	> 10,000 ppm
- downwind of control panel (see Figure K.9)	700 to 1000 ppm

TABLE K.2 (CONTD)

GAS CONCENTRATIONS ON OFFSHORE PLATFORMS

COMPANY:	G
PLATFORM:	A
DATE:	8/26/81

<u>AREA/EQUIPMENT</u>	<u>GAS CONCENTRATION</u> <u>ppm (total as methane)</u>
o Surge tank on platform above dead oil transfer pump	
- ambient background concentration	15 ppm
- at flange during inflow into tank	30 to 100 ppm
- downwind of tank	50 ppm
- downstairs to main deck (Figure K.6)	40 to 150 ppm
o 90-barrel test tank	
- at top of tank (vent closed)	100 to 200 ppm
- at sight glass	200 ppm
- at flanges	100 to 150 ppm
o Gas metering shack (Figure K.15)	
- inside shack	100 to 150 ppm
- outside shack where gas fittings are located	up to 1000 ppm
o Instrument Technician's office (Figure K.10)	15 ppm
o Compressor Room (see Figure K.11)	
- up steps to compressor room	1000 ppm
- at gas pipeline flanges outside room	> 10,000 ppm
- pressure display panel inside room	2000 to 3000 ppm
o Gas metering skid	100 to 350 ppm



FIGURE K.3. CELLAR DECK OF PLATFORM A

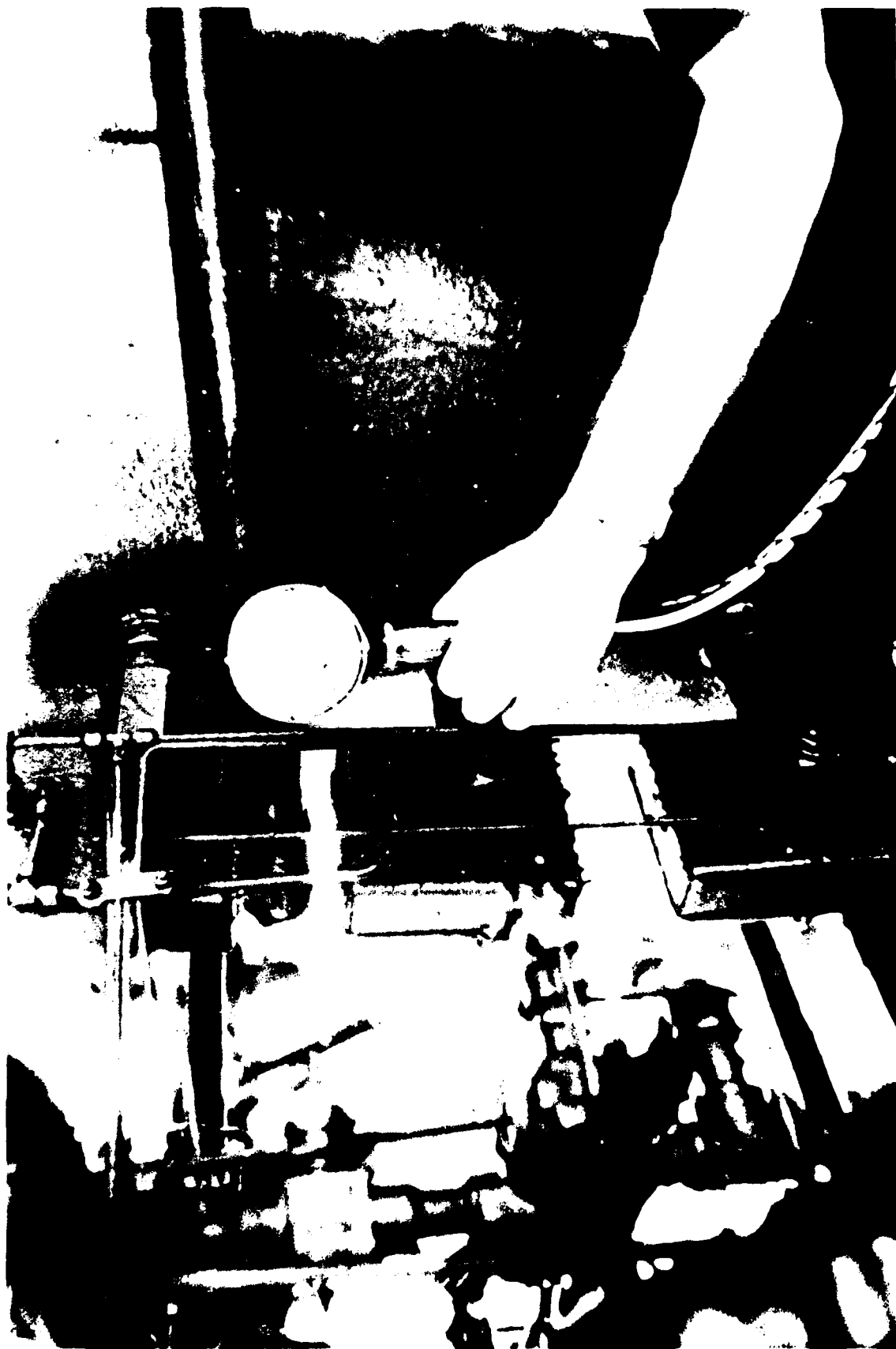


FIGURE K.4. EMISSIONS FROM INSTRUMENT GAS LINES ON CONTROLLER
FOR 65-BARREL S.M.P. TANK

ppm close to a level controller on the 65-barrel sump tank. This platform is one of the older platforms in the Gulf, being 25 years old. Fuel (natural) gas is used as an instrument gas instead of compressed air on this platform. Figure K.5 shows a float level indicator with its cover plate removed (or missing). A gas concentration of 700 ppm was measured inside the instrument body from emissions of instrument gas.

The main or upper deck contains low pressure and intermediate pressure separators to remove produced gas from oil and water. The gas is compressed, metered and sent into the sales gas pipeline. The produced oil and water are not separated on this platform, but are pumped through an oil metering run into a high pressure oil pipeline by the dead oil pump (dead oil means simply that the natural gas has been separated out).

As we climbed the stairway from the cellar deck to the main deck, the OVA began to indicate a total hydrocarbon concentration of from 30 to 70 ppm. At first, it was thought that a small vapor cloud might be coming from a waste bin containing discarded paint and solvent cans located on the deck. However, it was found that the gas emissions that we detected came from the dead oil pump and gas engine. These emissions were blown out over the main deck by the radiator cooling fan as shown in Figure K.6. Emissions of gas and oil vapor were found around both the dead oil transfer pump shown in Figure K.7 and the gas engine shown in Figure K.8. The most significant emission source was a leak of instrument gas from the control panel for the transfer pump and engine. This panel is enclosed on all sides, and fugitive emissions of instrument gas accumulate inside the panel. The mounting bracket for the #2 discharge pressure meter was either loose or broken, and instrument gas was escaping through the gap between the meter and the panel. Gas concentrations of from 700 to 1000 ppm were measured in the air downwind of the control panel as shown in Figure K.9.

Minor gas and vapor emissions were found around the surge tank located overhead of the dead oil transfer pump, and at the 90-barrel test tank. A gas metering shack (open on one side) gave readings of about 150 ppm inside the shack, but up to 1000 ppm outside the shack where the gas pressure lines were clustered (see Figure K.15).

The electrical technician has an office and work room on the production platform as shown in Figure K.10. The office is air-conditioned. A measurement of gas concentration gave a low reading, about 15 ppm, equal to the ambient concentration outside the building.

The fuel gas compressor room shown in Figure K.11 is the largest structure on the platform. The building has two doors and several glass and louvered windows. The doors and windows are usually kept closed as they are considered to be fire barriers. Fugitive emissions from the compressor, its fuel gas engine and the instrument control panel produced the distribution of gas concentration shown in Figure K.12. Gas concentration is continuously monitored in the compressor room by a General



FIGURE K.5. LEVEL DETECTOR ON SUMP TANK WITH COVER PLATE REMOVED



FIGURE K.6. MEASUREMENT OF GAS CONCENTRATION IN FRONT OF RADIATOR
FOR DEAD OIL PUMP AND GAS ENGINE

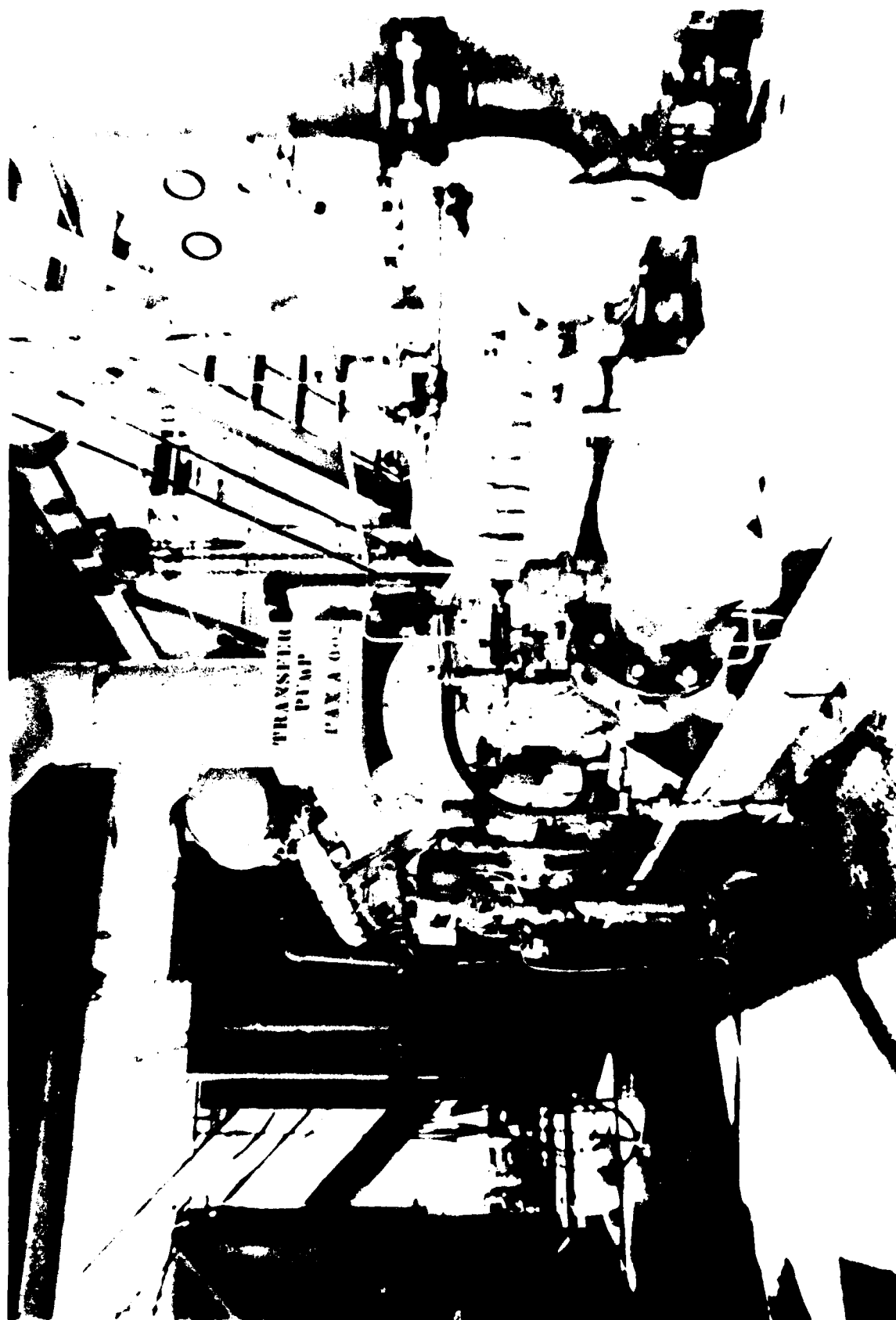


FIGURE K.7. DEAD OIL TRANSFER PUMP

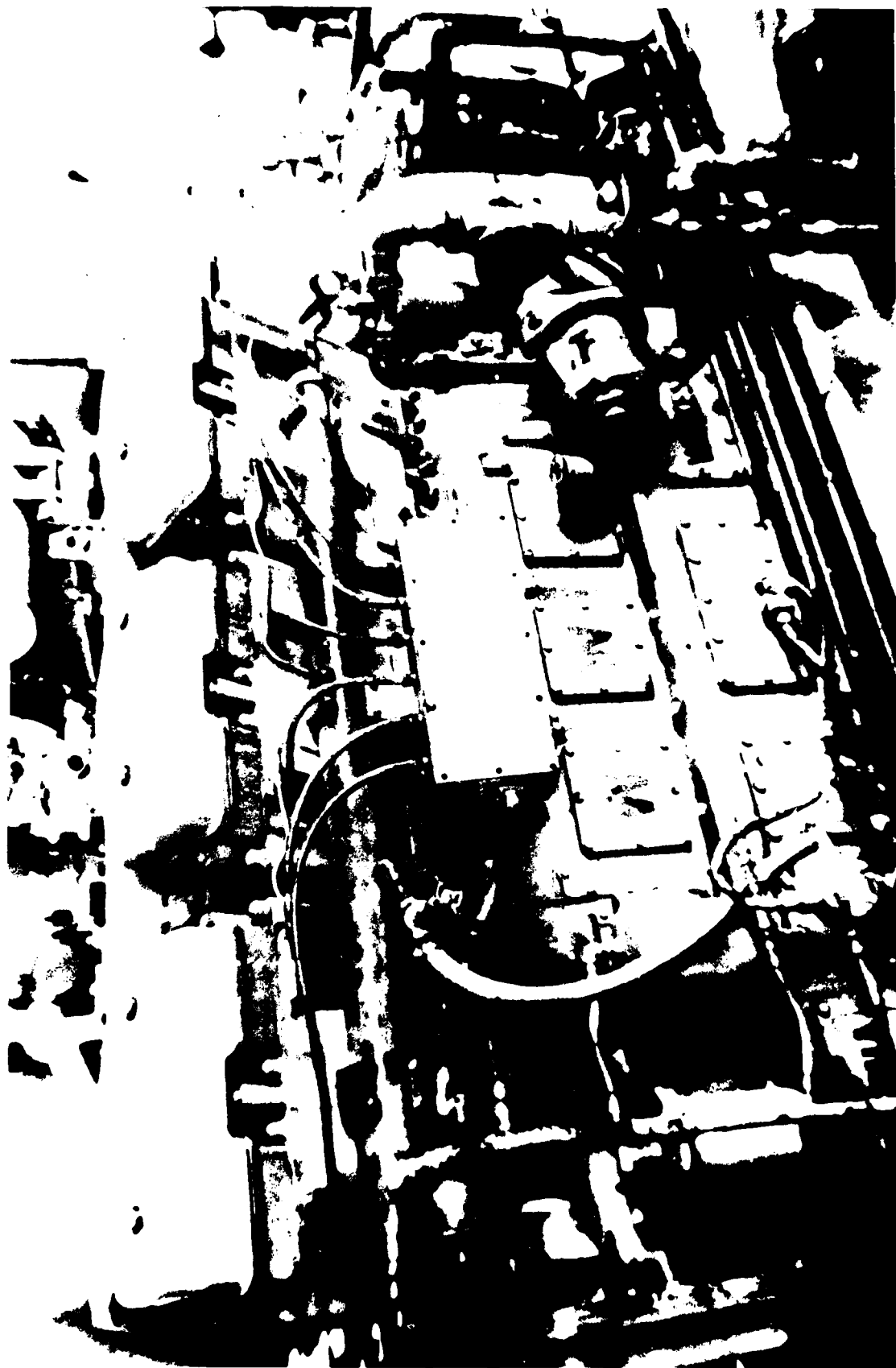


FIGURE K.8. FUEL GAS ENGINE DRIVING DEAD OIL PUMP

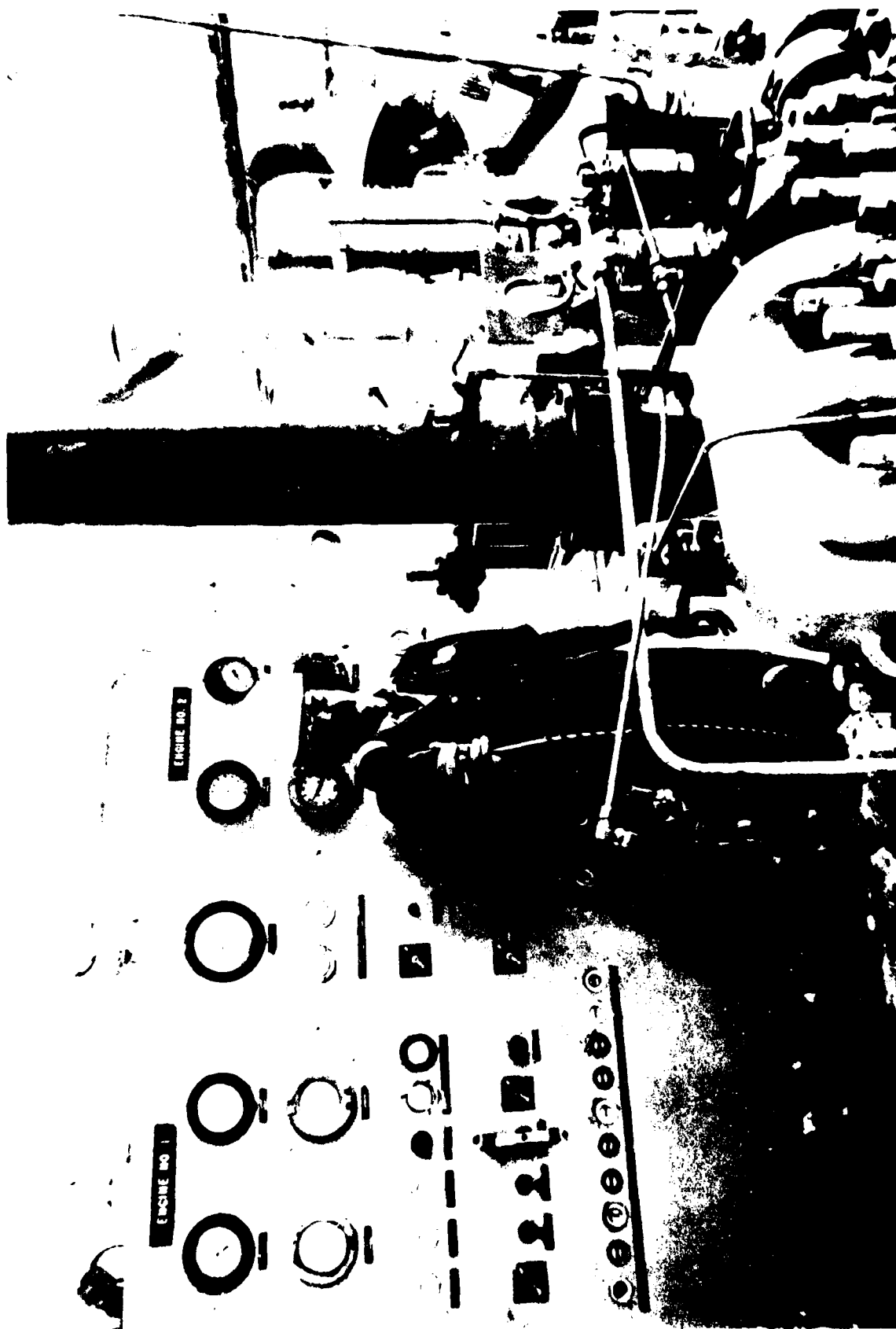


FIGURE K.9. GAS CONCENTRATION MEASUREMENT NEAR CONTROL PANEL FOR PUMP AND ENGINE



FIGURE K.10. ELECTRICAL TECHNICIAN'S OFFICE AND WORK AREA

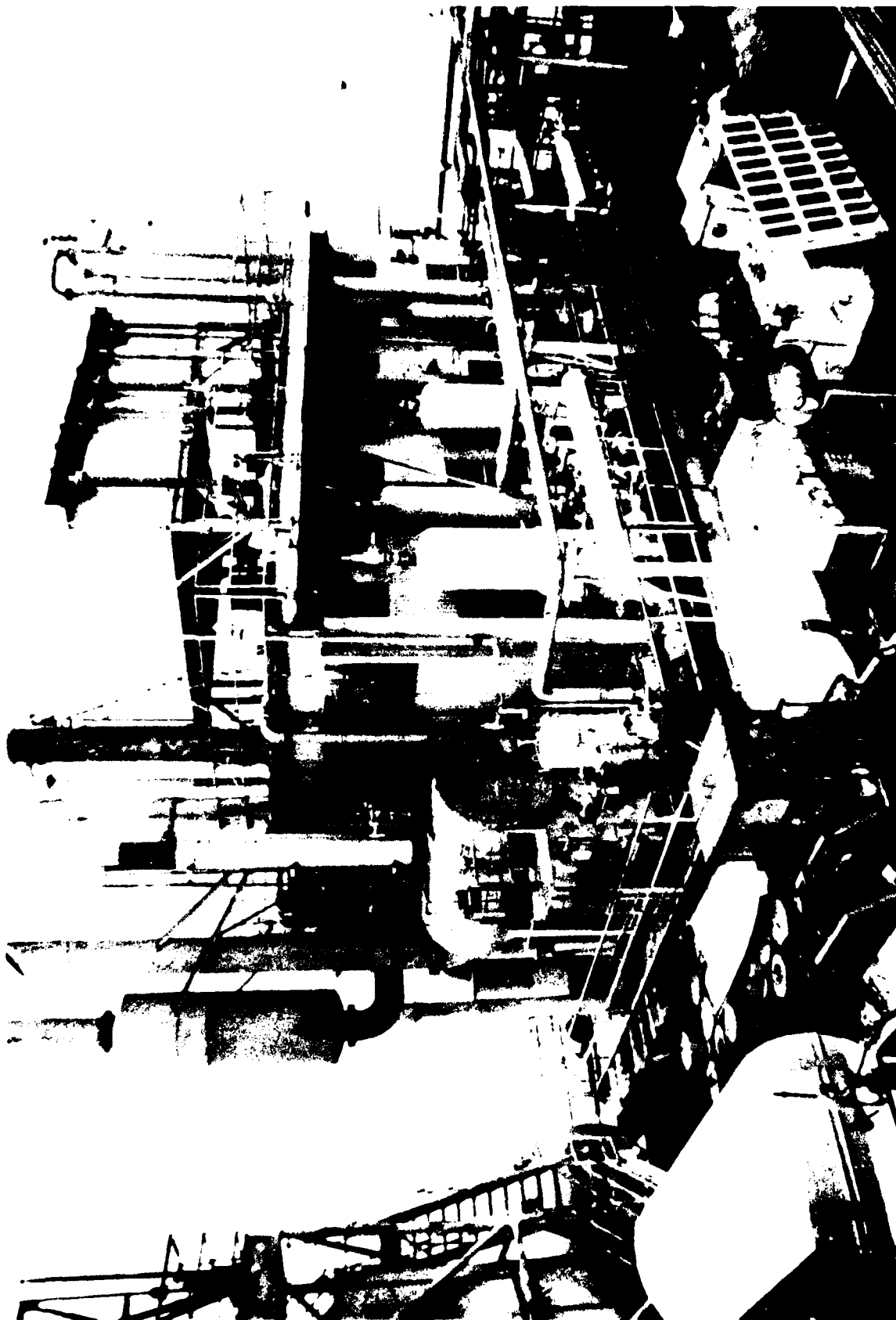
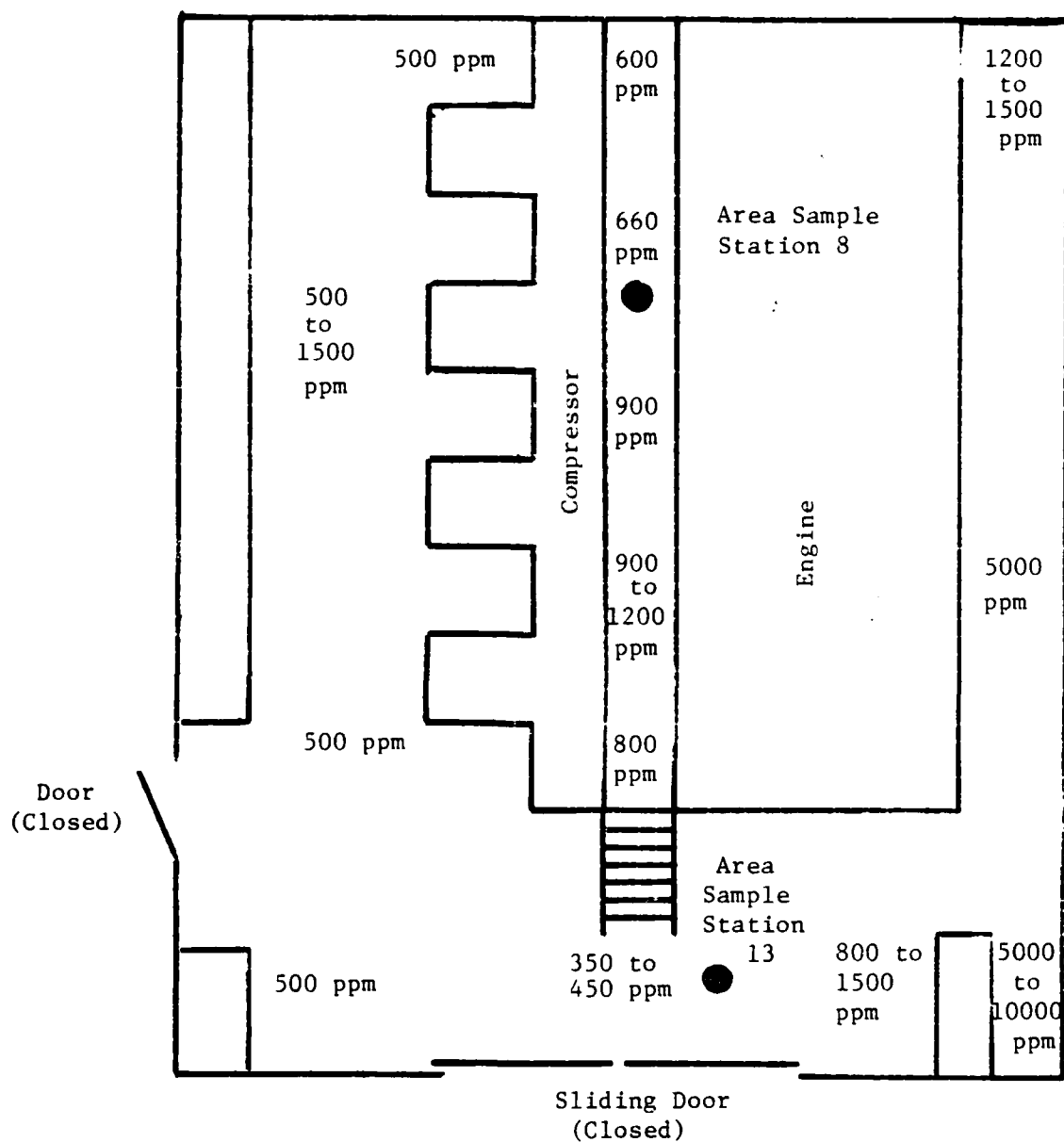


FIGURE K.11. HIGH PRESSURE GAS COMPRESSOR ROOM



Drawing Not
to Scale

FIGURE K.12 VARIATION OF TOTAL HYDROCARBON CONCENTRATION
IN GAS COMPRESSOR ROOM

Monitors Model 180 Combustible Gas Monitor, shown in Figure K.13. Gas sensors are mounted along the roof line and at floor level next to the instrument panel (shown in Figure K.14). The gas monitor reads the gas concentration at the sensor on a scale of 0 to 100% of the lower explosive limit (LEL). It is calibrated to give a reading of 50% LEL for a calibration gas sample of 2.5% methane in air (LEL = 5% for methane). The gas monitor sets off an audible alarm at 20% LEL (1% as methane) and shuts-in the platform at 60% LEL (3% as methane).

It should be noted that concentrations of 1% (10,000 ppm) and higher were measured at localized emission sources during the walk-through area survey. Samples of gaseous emissions were collected at three of the most prominent emission sources. Table K.3 shows the result of a gas chromatograph (GC) analysis of a source sample from the dead oil transfer pump instrument panel. The analysis showed that the emissions consisted of about 93% methane and progressively decreasing amounts of ethane through pentane. This distribution is characteristic of natural gas. The source concentration sample contained about 2.3% methane, which would cause a gas alarm to sound if it were sensed by the gas monitor system.

Table K.4 shows the GC analysis of a source sample collected within the compressor room instrument panel. This panel contains the complex arrangement of instrument gas piping shown in Figure K.16. Fugitive emissions from piping connections collect and cause the gas concentration inside the instrument panel to increase. Table K.4 indicates that the gas concentration inside the instrument panel exceeded 10% as methane. However, the concentration within the compressor room, outside the panel, did not exceed 1% as methane.

Table K.5 shows the results for a GC analysis of a source sample collected on the cellar deck at a leaky valve stem on the oil and gas pipeline coming from platform B. Note that the concentration distribution contains about 92% methane, characteristic of natural gas. The source concentration exceeded 4.8% as methane, but since the leak area was very small (really just a "pin hole" leak) the gas cloud from the leak was quickly diluted by the wind.

Area samples of 10-minute duration were collected at two locations in the closed compressor room shown in Figure K.12. Sample number 8 was taken at man breathing height along the walkway above the compressor and gas engine. The results of the GC analysis for sample 8 are given in Table K.6. The total hydrocarbon measurement of 950 ppm is in agreement with results obtained from the walk-through survey. Sample number 13 was taken at breathing height in front of the sliding door about 2m from the compressor instrument panel. Table K.6 also shows the GC analysis for this sample. The total hydrocarbon measurement of 850 ppm is also in accord with the results from the walk-through survey. With these levels of natural gas concentration the air in the compressor room is safe to breathe by current standards.

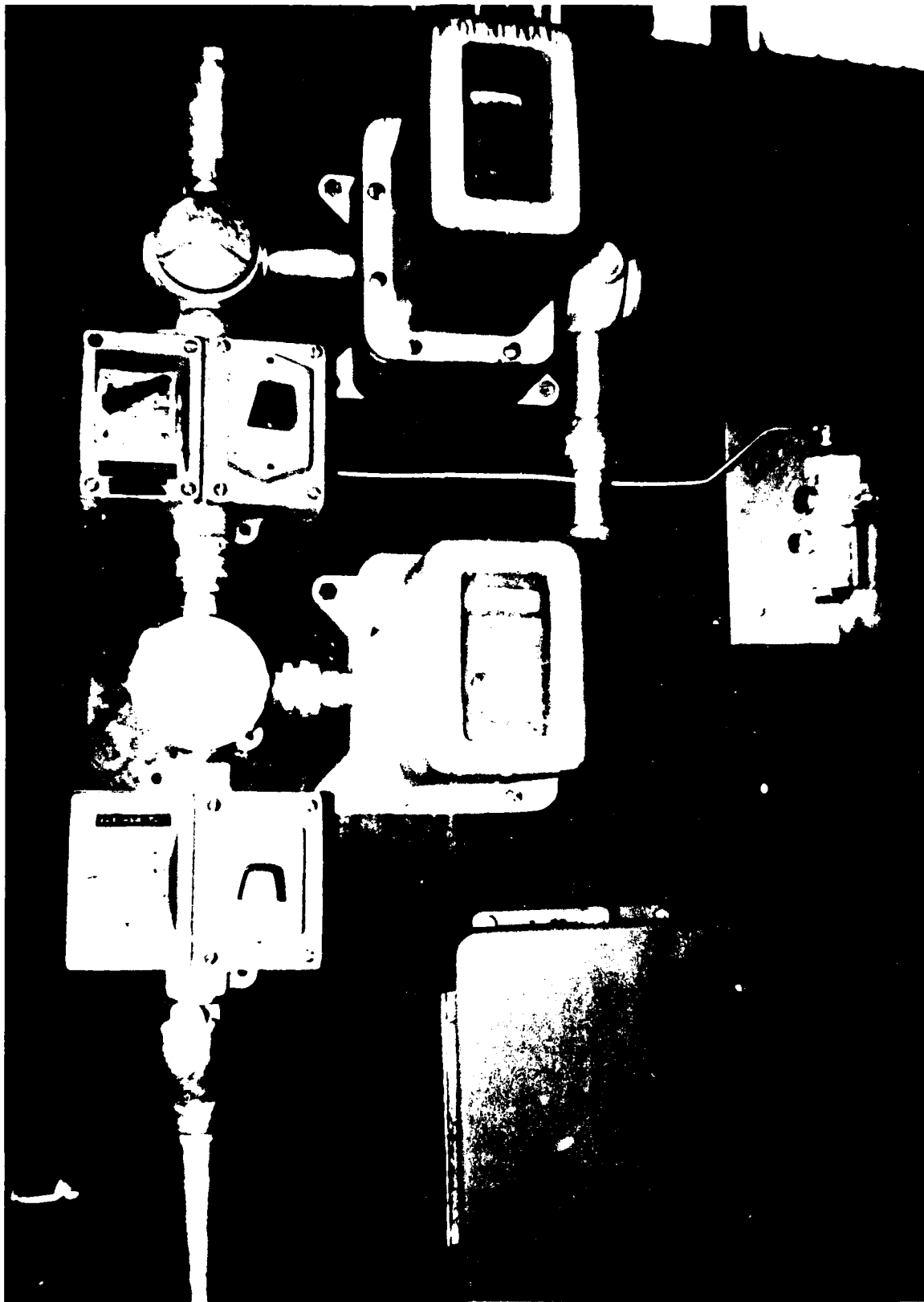


FIGURE K.13. COMBUSTIBLE GAS MONITOR IN COMPRESSOR ROOM



FIGURE K.14. COMBUSTIBLE GAS SENSOR IN COMPRESSOR ROOM

TABLE K.3
RESULTS OF SOURCE SAMPLING FROM OIL TRANSFER PUMP INSTRUMENT PANEL

Sample Number	Dilution Ratio	C ₁ methane ppm	C ₂ ethane ppm	C ₃ propane ppm	i C ₄ i-butane ppm	C ₄ n-butane ppm	i C ₅ i-pentane ppm	C ₅ n-pentane ppm	i C ₆ i-hexane ppm	C ₆ n-hexane ppm
10	1:1	24,000	940	370	128	100	49	33	*	*
10	1:1	21,500	1000	430	128	100	49	41	*	*
Average		22,800	970	400	128	100	49	37	*	*
Percentage Distribution of Hydrocarbons		93.1%	4.0%	1.6%	0.5%	0.4%	0.2%	0.2%	<0.1%	<0.1%

* Peak height too small to resolve.

TABLE K.4

RESULTS OF SOURCE SAMPLING FROM COMPRESSOR ROOM INSTRUMENT PANEL

Sample Number	Dilution Ratio	C ₁ methane ppm	C ₂ ethane ppm	C ₃ propane ppm	i C ₄ i-butane ppm	C ₄ n-butane ppm	i C ₅ i-pentane ppm	C ₅ n-pentane ppm	i C ₆ i-hexane ppm	C ₆ n-hexane ppm
9		100,000	3900	1800	740	560	220	200	*	*
Percent Distribution of Hydrocarbons		93.1%	3.6%	1.7%	0.7%	0.5%	0.2%	0.2%	<0.1%	<0.1%

* Peak height too small to resolve.

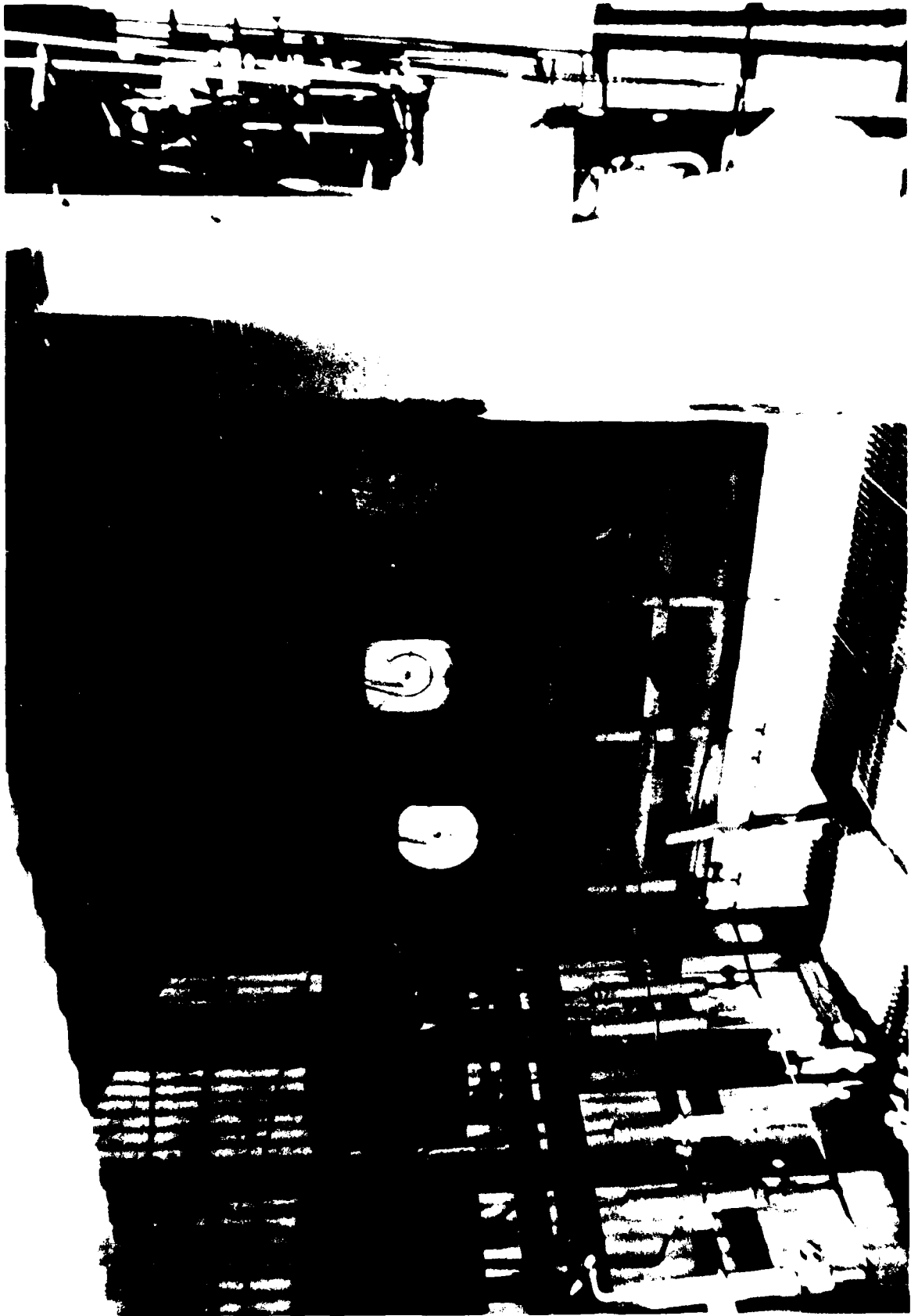


FIGURE K.15. GAS FLOW METERING SHACK

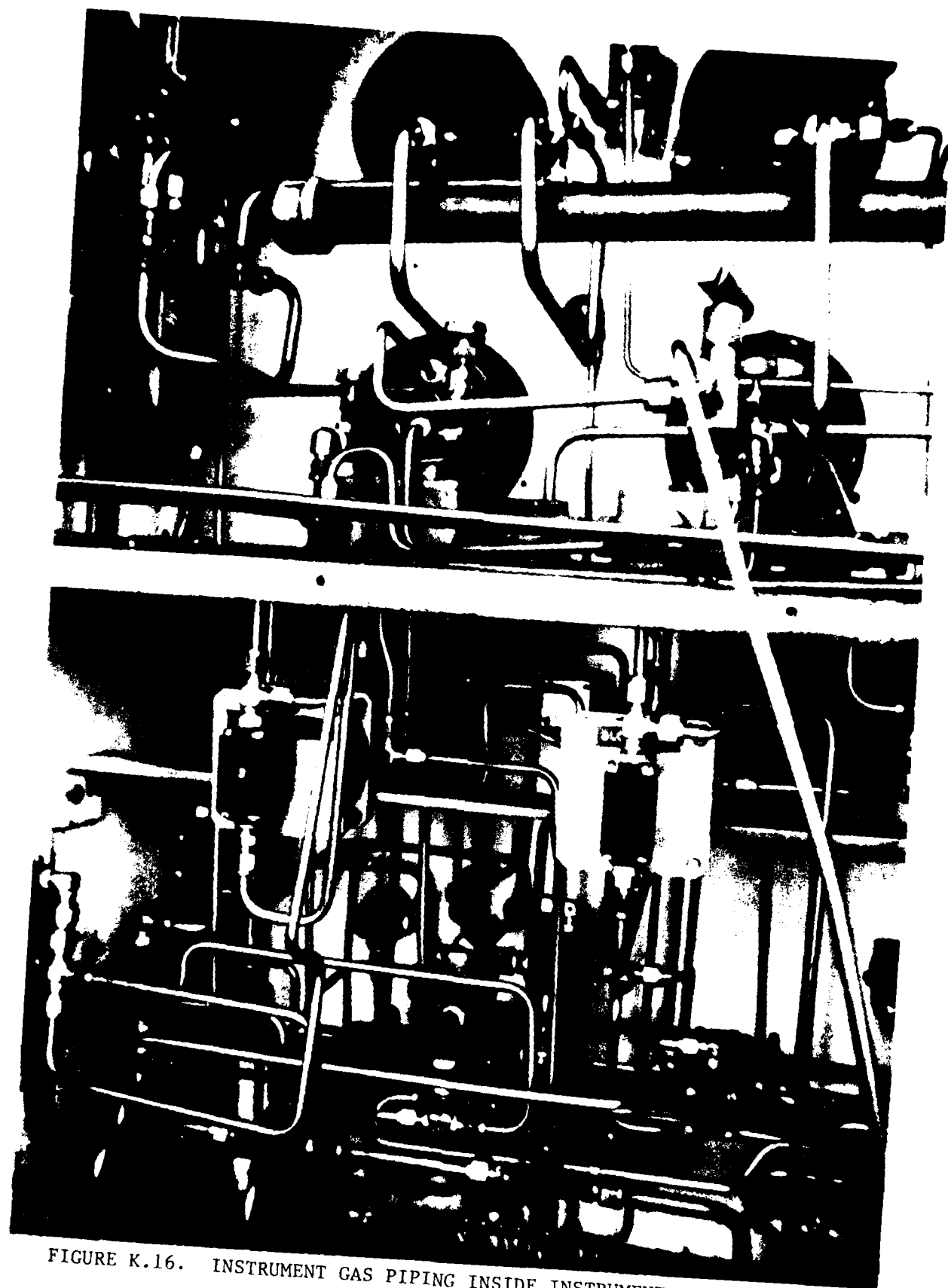


FIGURE K.16. INSTRUMENT GAS PIPING INSIDE INSTRUMENT PANEL IN COMPRESSOR ROOM

TABLE K.5

RESULTS OF SOURCE SAMPLING AT LEAKY VALVE STEM ON OIL AND GAS PIPELINE FROM PLATFORM B

Sample Number	Dilution Ratio	C ₁ methane ppm	C ₂ ethane ppm	C ₃ propane ppm	i C ₄ i-butane ppm	C ₄ n-butane ppm	i C ₅ i-pentane ppm	C ₅ n-pentane ppm	i C ₆ i-hexane ppm	C ₆ n-hexane ppm
2		48,000	2300	1050	380	350	130	78	*	*
2		48,000	2100	900	350	360	110	78	*	*
Average		38,000	2200	975	365	355	120	78	*	*
Percentage Distribution of Hydrocarbons		92.1%	4.2%	1.9%	0.7%	0.7%	0.2%	0.1%	<0.1%	<0.1%

TABLE K.6

RESULTS OF AREA SAMPLING IN THE COMPRESSOR ROOM

Sample Number	Total Hydrocarbon Concentration ppm	C ₁ methane ppm	C ₂ ethane ppm	C ₃ propane ppm	1 C ₄ 1-butane ppm	C ₄ n-butane ppm	1 C ₅ 1-pentane ppm	C ₅ n-pentane ppm	1 C ₆ 1-hexane ppm	C ₆ n-hexane ppm
8	950	840	29	14	6	5	*	*	*	*
13	850	770	28	14	4	5	*	*	*	*

* Peak height too small to resolve.

This observation was a useful test of the method proposed for field evaluation of gas and vapor concentration on production platforms. The key conclusions from this test are the following:

- o A portable gas chromatograph can resolve the gaseous and vapor constituents of emissions from offshore production platforms.
- o Emissions from gas engines, compressors, transfer piping, and well heads appear to consist primarily of natural gas with approximately 94% methane and progressively decreasing amounts of ethane, propane, butane and pentane.
- o Fugitive emissions inside instrument panels and enclosed spaces can collect and increase the gas concentration to levels that approach or exceed the lower flammability limit for methane.
- o Gas concentrations at localized fugitive emission sources may also exceed the lower flammability limit.
- o The level of gas concentration present in the compressor room, office spaces, and enclosed work spaces does not exceed the maximum concentration allowable by current standards.

K.2 OFFSHORE DRILLING RIGS

From 8/11/81 to 8/13/81, a project observation team visited two offshore drilling rigs for the purpose of measuring gas concentrations at the shale shaker and observing skin contact with the drilling fluid during drilling. The first rig was located on a semi-submersible platform. Water depth at this location was over 300m (1000 ft.). During the observation the water base drilling mud was returning to the surface gas-cut by up to 1 lb/gal, and barite was being added to increase the mud weight and reduce gas cutting.

The shale shaker was located in a small room on the semi-submersible. A large, 1m diameter fan was set into the wall of the room, as shown in Figure K.17, to draw a strong flow of air past the shale shaker. Air entered the room through two open doorways and five windows as indicated in Figure K.18. Area survey measurements of gas concentration in the shale shaker room were made on three separate occasions with the portable organic vapor analyzer (OVA). Figure K.19 shows values of total hydrocarbon concentration at different locations in the room. The highest values of concentration, from 1000 ppm to 2500 ppm, were measured right above the mud surface. Bubbles of gas were seen breaking at the mud surface as shown in Figure K.20. Although the emission of gas from the mud continued for a long time, the excellent ventilation air flow produced by the fan prevented the gas concentration in the room from reaching dangerous levels.

Gas concentration measurements were repeated after mud circulation had been stopped and restarted. Figure K.21 shows that a peak concentration of 4500 ppm was measured above the mud surface, and a maximum value of 400 ppm at man breathing height near the fan inlet. The location is important because the mudman often stands here (Figure K.22) when taking samples of drilling fluid for mud weight and viscosity determination.

Gas concentration measurements were made again one day later with the results shown in Figure K.23. The peak concentration above the mud surface had increased to values ranging from 7000 to 10,000 ppm. The maximum concentration at man breathing height had also increased to values from 300 to 700 ppm in front of the fan.

Samples of the air at man breathing height were collected in inert bags for a period of 10 minutes as shown in Figures K.24 and K.25. Sample 15 gave a gas concentration of 40 ppm above the sink where mud viscosity is measured. Sample 17 gave a concentration of 330 ppm in front of the fan where mud samples were drawn. Sample 10 produced a value of 50 ppm at the location where the mud weight measurement was made. Locations 9, 11, and 16 corresponded to locations where the mudman stood while washing down the shale shaker and mudroom floor. Concentration values were 30 ppm, 26 ppm, and 24 ppm, respectively at these three locations.



FIGURE K.17. FAN IN SHALE SHAKER ROOM TO DRAW AIR PAST SHALE SHAKER

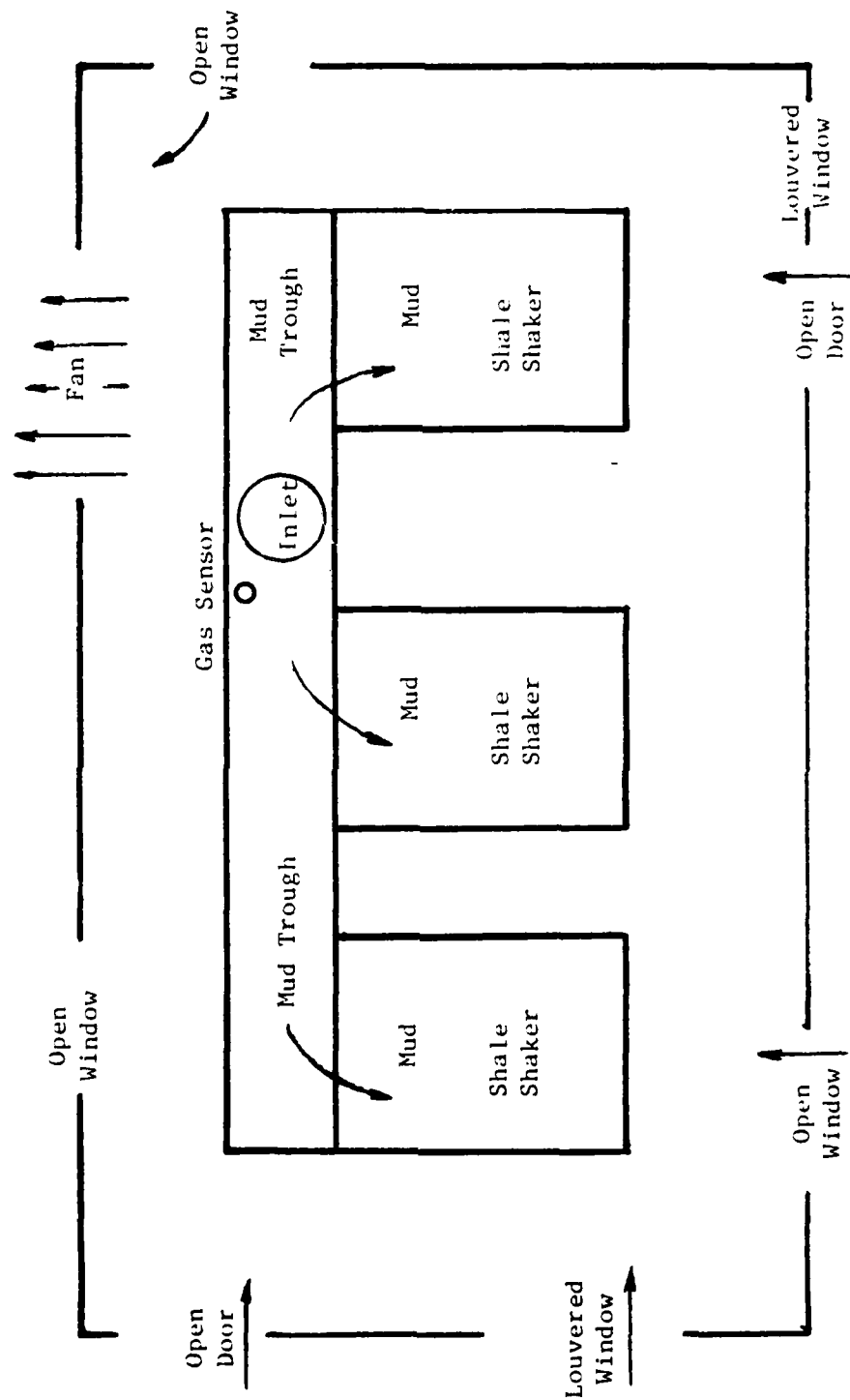


FIGURE K.18. DRAWING OF SHALE SHAKER ROOM SHOWING VENTILATION AIR CURRENTS

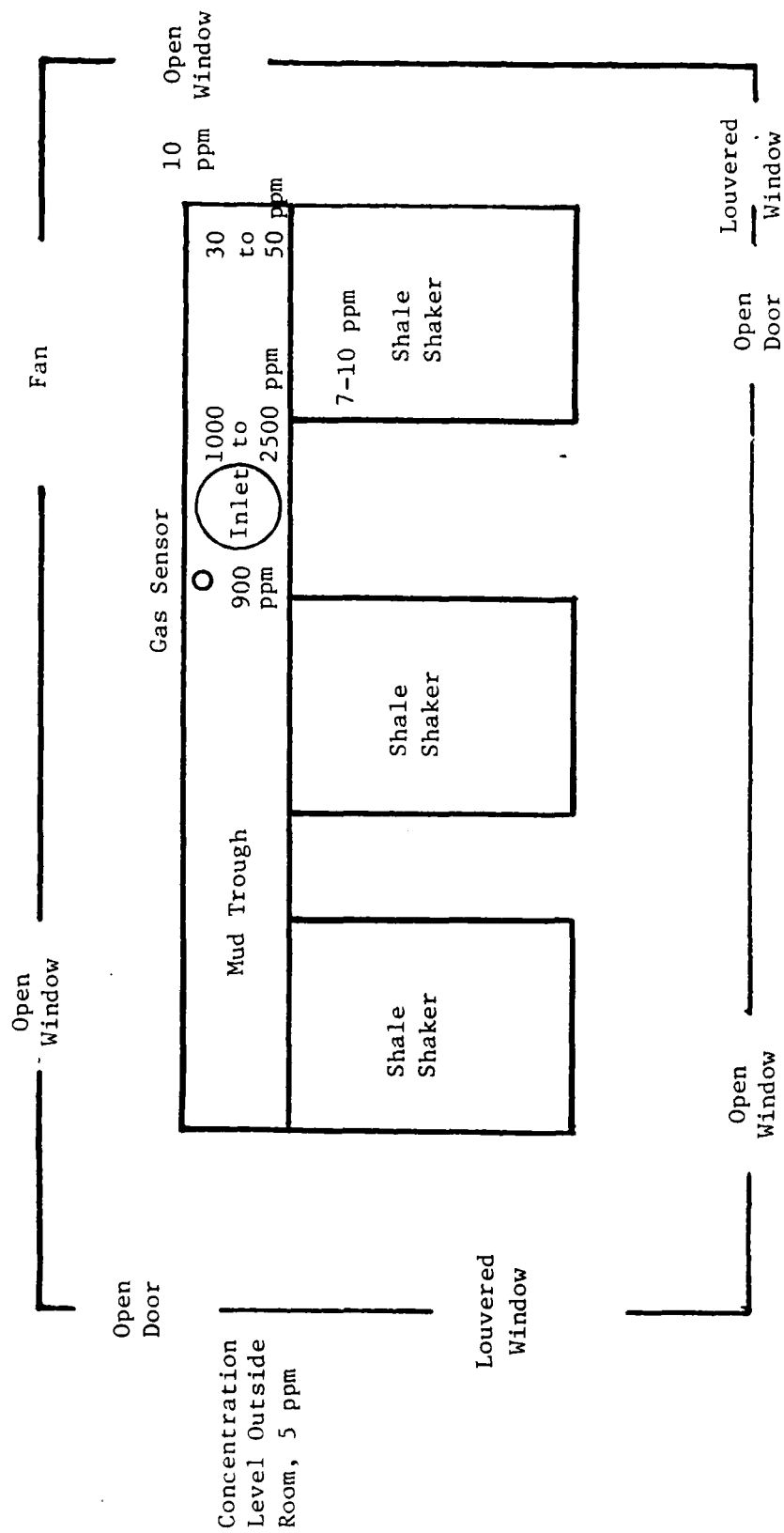


FIGURE K.19 TOTAL HYDROCARBON CONCENTRATION READINGS INSIDE SHALE SHAKER ROOM

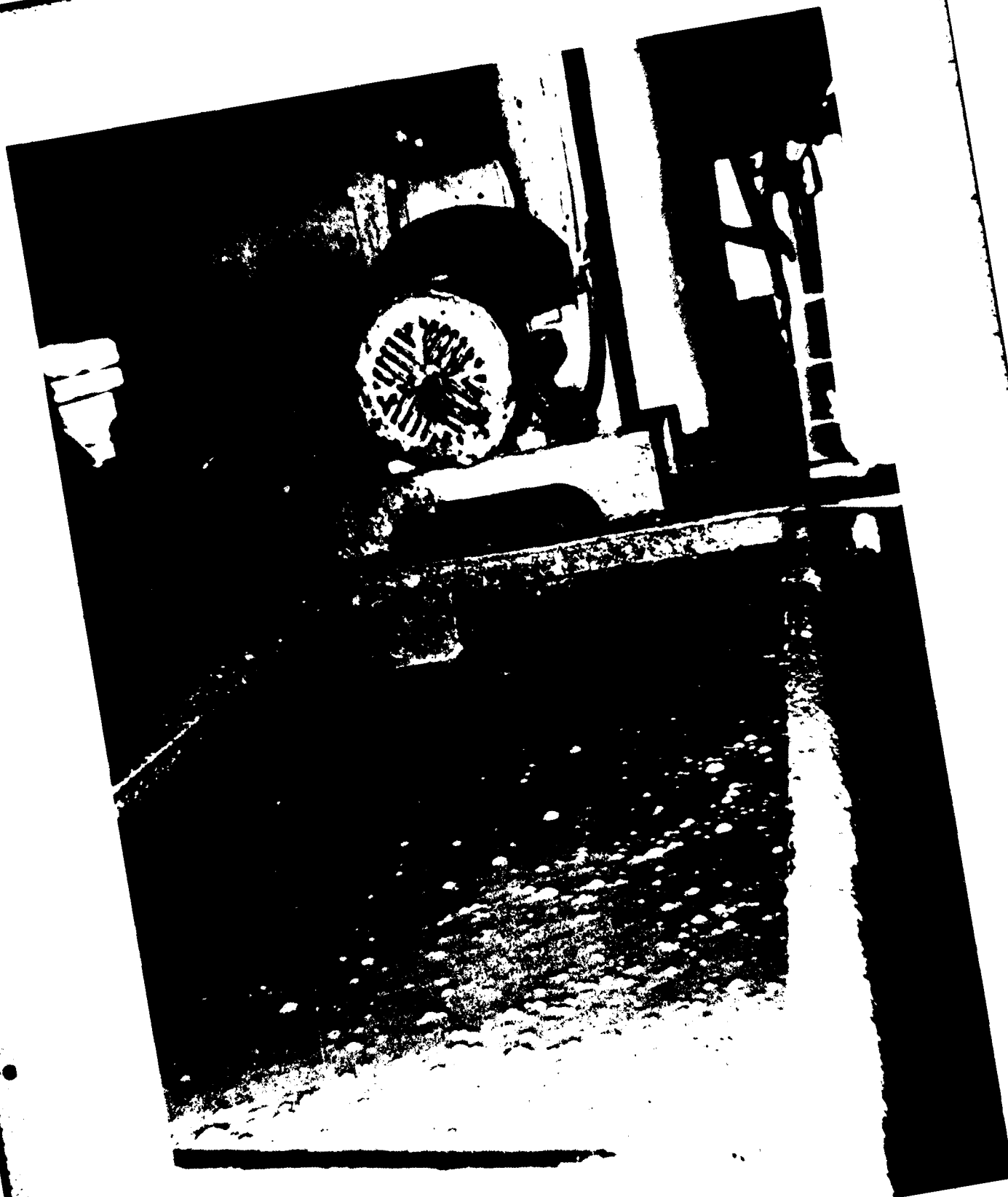


FIGURE K.20. GAS BUBBLES BREAKING AT MUD SURFACE IN SHALE SHAKER

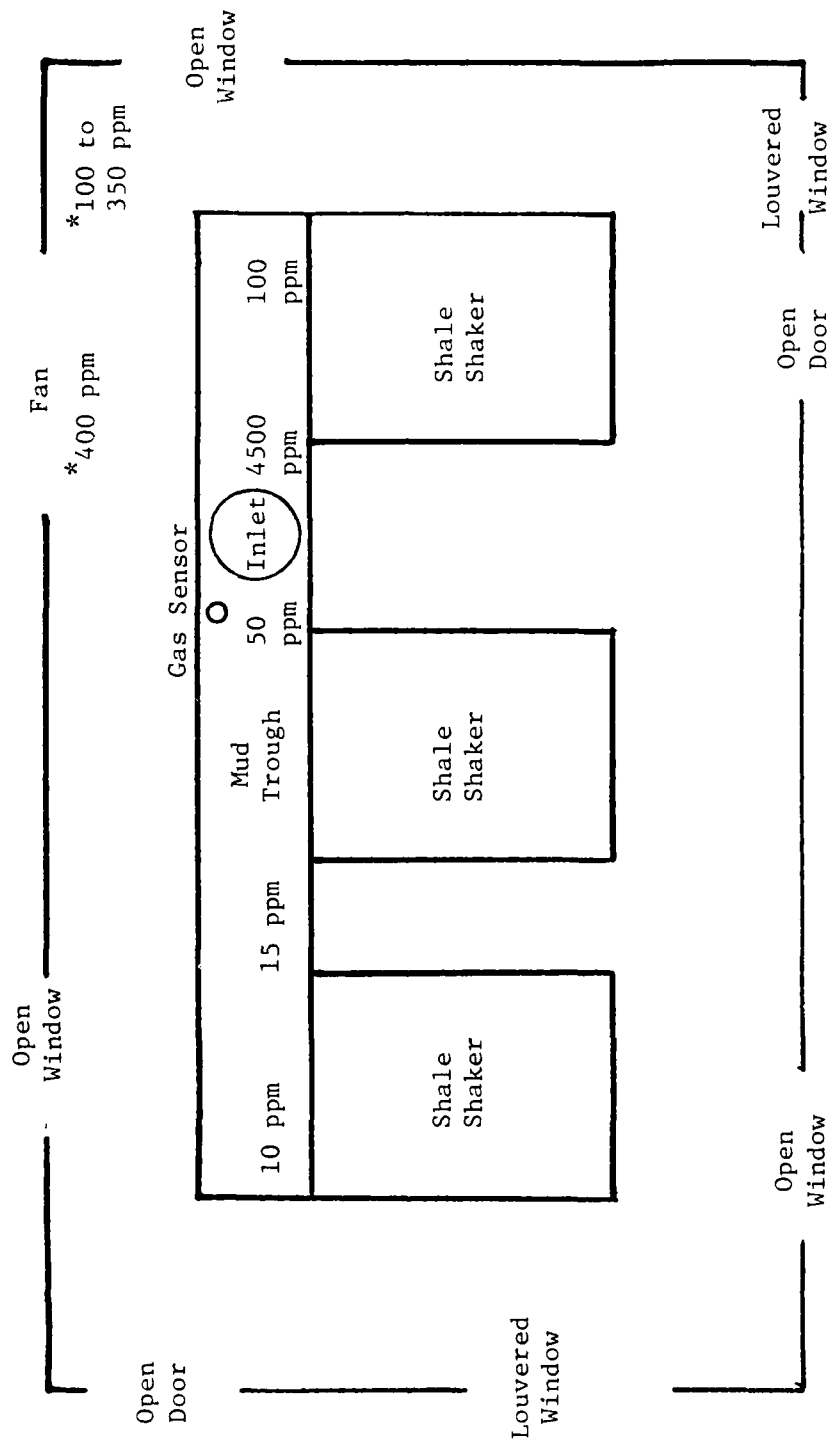


FIGURE K.21 REMEASUREMENT OF TOTAL HYDROCARBON CONCENTRATION INSIDE SHALE SHAKER ROOM

*At Breathing Height. Other Readings are above mud trough.



FIGURE K.22. NUDMAN TAKING SAMPLES OF DRILLING FLUID FOR MUD WEIGHT AND VISCOSITY DETERMINATION

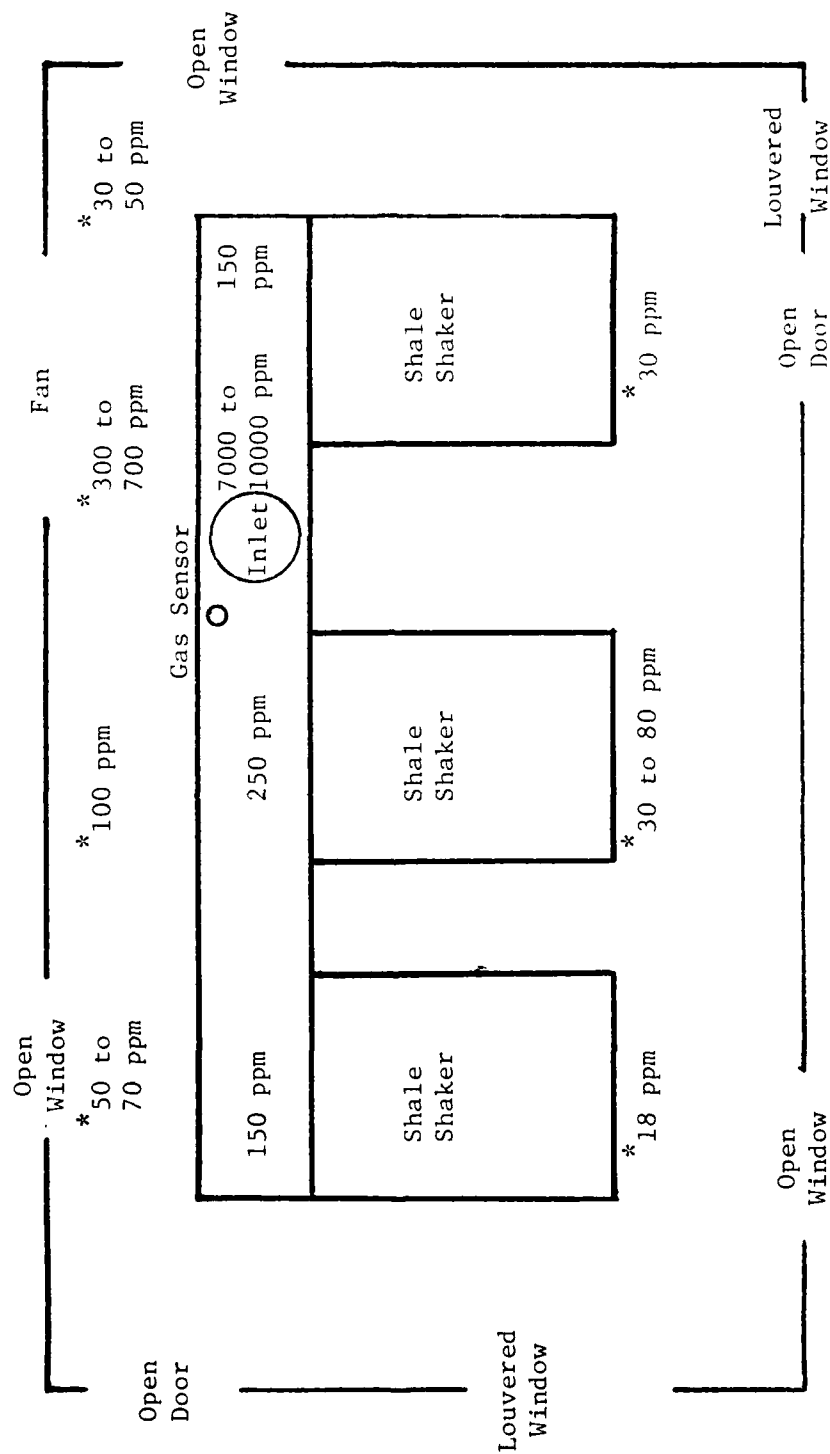


FIGURE K.23 LATER MEASUREMENT OF TOTAL HYDROCARBON CONCENTRATION INSIDE SHALE SHAKER ROOM.

*Measured at breathing height. Other readings are above mud trough.



FIGURE K.24. COLLECTING A 10-MINUTE SAMPLE OF THE AIR AT BREATHING HEIGHT IN THE SHALE SHAKER ROOM

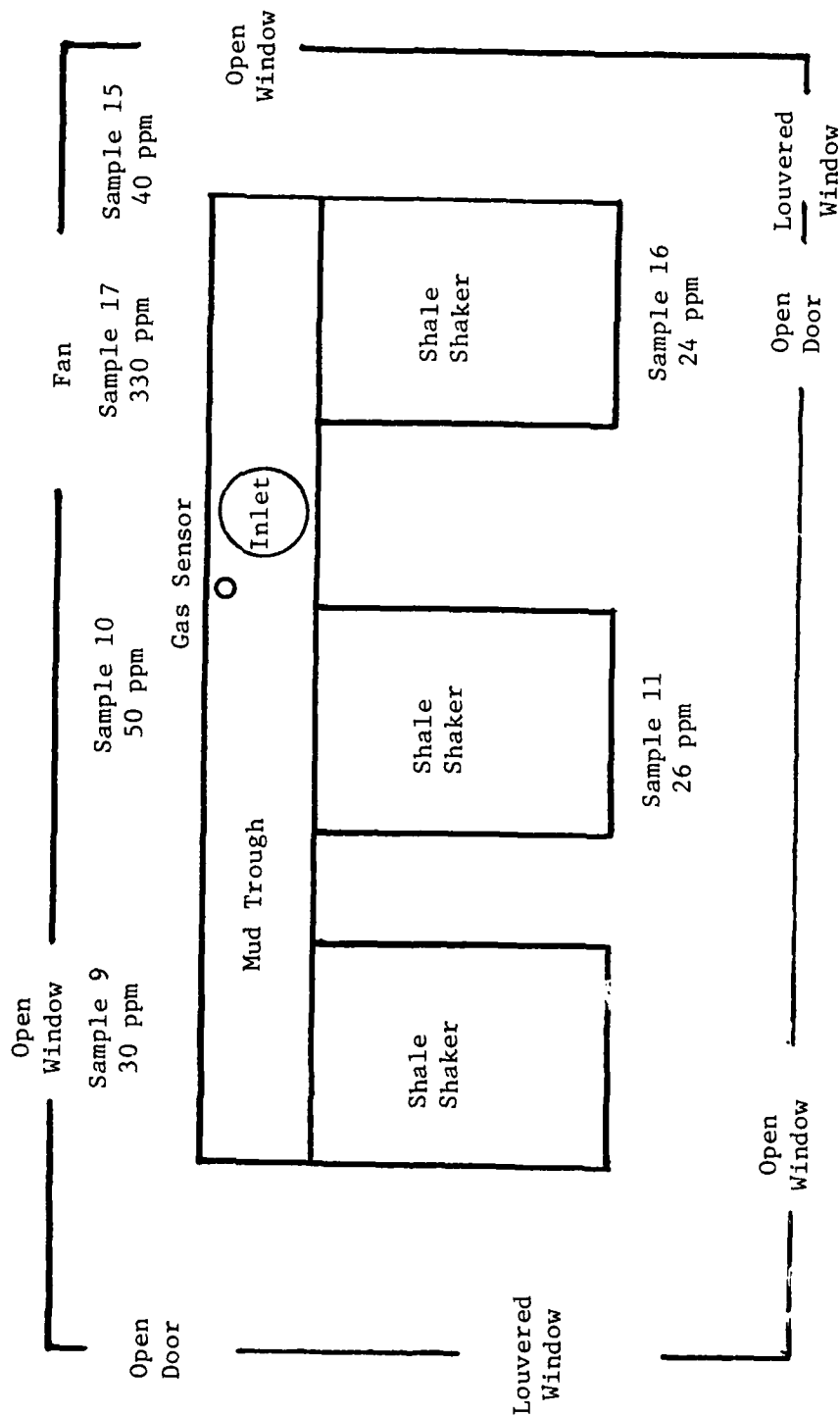


FIGURE K.25 RESULTS OF 10-MINUTE AVERAGE AREA SAMPLING IN SHALE SHAKER ROOM

A mud logging unit was present on the semi-submersible platform during this observation. The mud logging crew were monitoring the level of gas in the mud with a gas sensor located on the shale shaker. They also analyzed mud samples for gas composition periodically by collecting a mud sample, heating it to drive out gas and vapor, and analyzing the vapor space with a gas chromatograph. The chromatograph provided a gas concentration distribution for methane, ethane, propane, butane and pentane. The most recent sample had contained nearly all methane.

The concentration levels shown in Figure K.25 for a gas containing mostly methane, ethane and propane are not considered hazardous by current standards. This would indicate that gas emissions from gas-cut mud will not present a health or safety hazard to a mudman working in a shale shaker room with good ventilation. However, in a poorly ventilated room, the mud gas emissions could accumulate and produce gas concentrations that approach health and flammability limits.

In order to reduce the amount of gas entering into the mud, barite was added to increase the mud weight and to balance the hydrostatic pressure in the gas bearing formation. On this rig, the pumper (in charge of the mud pumps) was responsible for adding barite and other chemicals through the bulk solids hopper. We observed the pumper adding caustic soda (Figure K.26) and ferrochrome lignosulfonate to the drilling fluid. While opening and adding bags of chemicals, the pumper remained within 1 to 2 meters of the hopper. Figure K.27 shows a caution sign requiring protective equipment that was displayed prominently in the mud makeup area. A second caution sign displayed in the same area specified the first aid procedure for caustic burns as follows:

First Aid for Caustic Burns

Skin

- (1) Flush burn liberally with water hose for 5 minutes.
- (2) Remove clothing from area involved.
- (3) Rinse burn with a solution of vinegar and water.

Eyes

- (1) Wash eyes quickly with potable water in living quarters.
- (2) Hold the eye lids open and continue flushing for at least 15 minutes.
- (3) Do not use vinegar in the eye.

The pumper was not wearing gloves, goggles, or a dust mask when mixing mud chemicals until he became aware that we were recording and photographing his activities. He left the mud mixing area and returned



FIGURE K.26. ADDING CAUSTIC SODA TO THE DRILLING FLUID



FIGURE K.27. ADDING CAUSTIC SODA AND FERROCHROME LIGNOSULFONATE TO THE DRILLING FLUID

with gloves, goggles, and a dust mask which he wore for the remainder of our observation. We asked him about his experiences with mud chemicals. He said he had experienced a caustic soda burn on his skin, and had damage to his shoes when caustic soda ate through the leather above the soles.

We observed activities on the drill floor and found it to be in very clean condition. Although mud was spilled onto the floor when the kelly was uncoupled from the drill pipe (Figure K.28), the rotary table, the slips and the drill floor were washed down after a new length of pipe was added to the drill string (Figure K.29) and the drilling was resumed. The roughnecks had very little contact with the drilling mud during our observations on the drill floor.

After concluding the observation of drilling activities on the semi-submersible, we moved to the drilling rig and tender barge shown in Figure K.30. The rig had finished drilling a well to total depth with oil base mud and had completed a cementing job. The crew were preparing to drill through the cement plug prior to displacing the oil base mud with a calcium bromide completion solution. The mud pits and pumps as well as crew sleeping quarters and galley facilities were all contained onboard the tender barge. Figure K.31 shows the mudpit room on the barge. The platform contained the drilling rig, the shale shakers and a cuttings washer needed to remove oil base mud from the cuttings before they are discharged into the sea.

The oil base mud was an invert emulsion mud containing about 84% oil and 16% water. The "company man" on the rig said that the mud can be removed from the skin by washing with "Lava" or "Borax" soap. Oil stained clothes are laundered with the same detergent that is used in the cuttings washer. When displacing the oil base mud from the well, it is normal practice to circulate 50 barrels of polymer fluid, followed by 50 barrels of detergent, followed by the calcium bromide. They take the calcium bromide from a barge and run the oil base mud into their reserve tanks. When fully displaced, the oil base mud is pumped into the barge which returns to shore and discharges the mud to a storage tank.

The tender barge displayed a notice to the crew members advising protective procedures to be used during the handling of completion fluids such as saturated calcium bromide. These are as follows:

- o When mixing dry solid material, stand upwind of the hopper.
- o Do not shake the empty bag to avoid creating dust.
- o Use of a skin barrier cream was advised for personnel contacting the solution.
- o After work, it was advised that men rinse their hands for 15 minutes under running water (with washing of hands) to avoid irritation and infection.

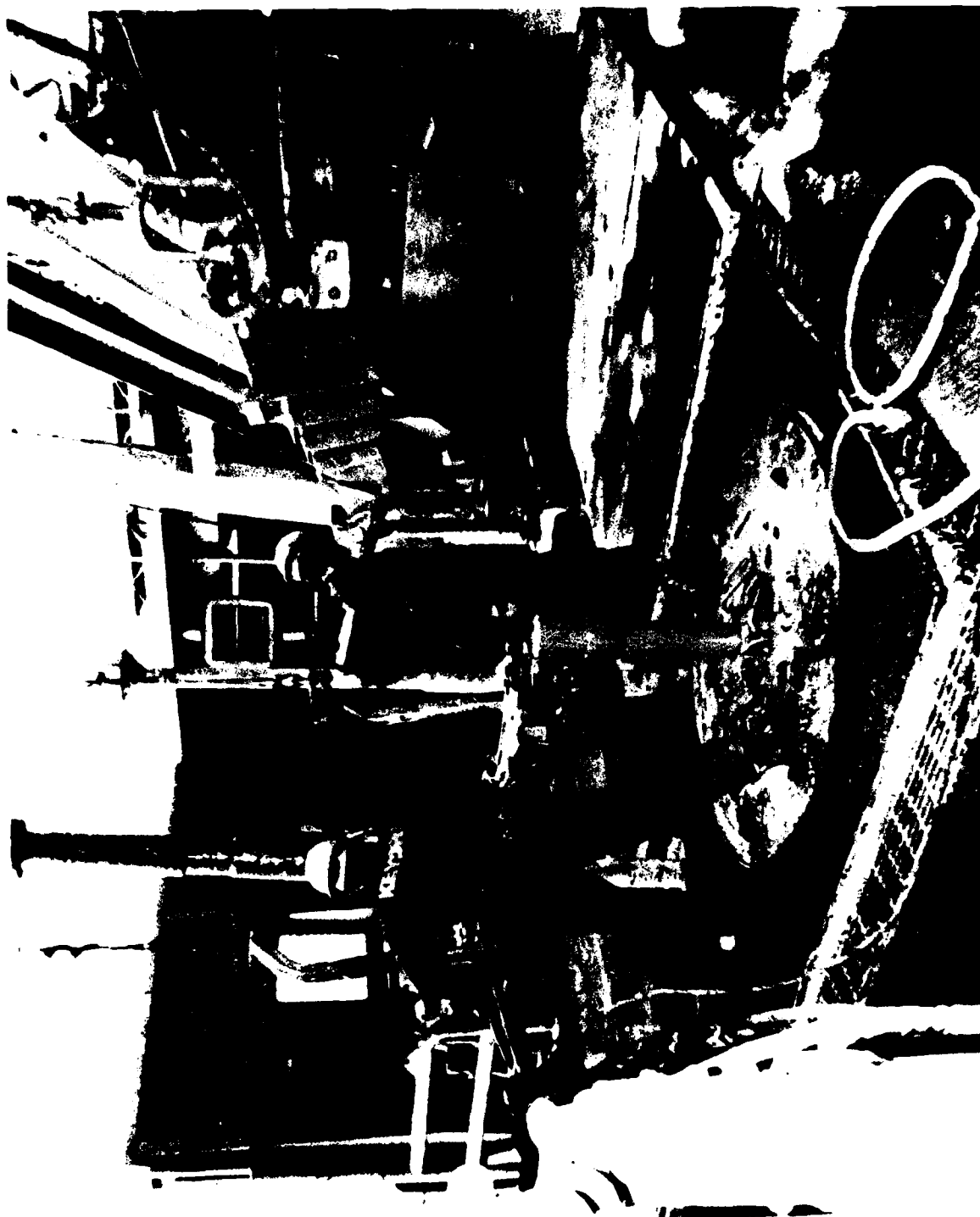


FIGURE K.28. UNCOUPLING THE KELLY FROM THE DRILL PIPE



FIGURE K.29. WASHING DOWN THE SLIPS AND ROTARY TABLE DURING DRILLING

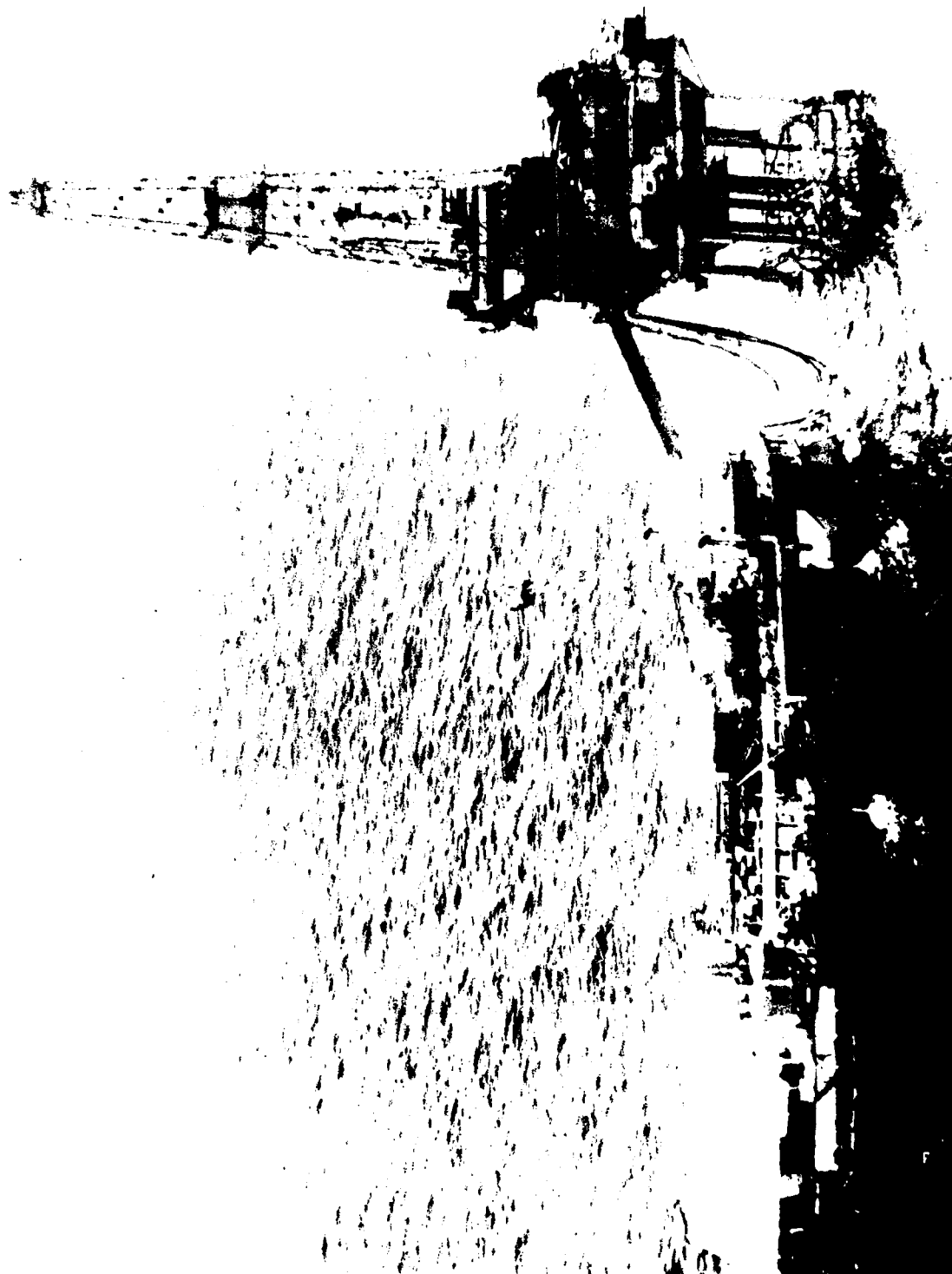


FIGURE K.30. DRILLING PLATFORM WITH ATTENDANT TENDER BARGE



FIGURE K.31. MUDROOM ON TENDER BARGE

- o Use of a NIOSH approved respirator was advised to protect against inhalation of aerosol droplets

Drilling of the cement plug with oil base mud took place in the last night of our observation. The oil base for this mud is diesel fuel, and some vapor is evolved during drilling operations. Vapor concentrations ranging from 40 to 80 ppm were measured around the shale shaker during drilling. In the mudpit room on the barge, maximum concentrations of from 50 to 100 ppm were measured at breathing height. Above the mud surface in the mud return trough, a maximum value of 175-200 ppm was measured.

We observed activities on the drill floor for a period of about two hours. It appeared that the roughnecks had difficulty keeping mud off their clothes and their skin. The drill pipe, kelly, and drill floor could not be washed with water to remove the mud. Whenever a roughneck touched the drill pipe or kelly, the mud was transferred to him. Figure K.32 shows the men working on the drill floor. The coveralls of the roughneck at the right of the figure were covered with mud over 15 to 20% of their surface area.

Earlier we had asked some of the roughnecks for their experiences with oil base mud. Their comments can be summarized as follows:

- o It was felt that the detergent used in the cutting washer was harsh on the skin.
- o It was felt that skin contact with the oil base mud can cause a rash. However, the contact time needed to produce a rash varies with the individual. One worker said that skin contact for 10 minutes would make him develop a rash.
- o Vapors from the diesel fuel worsen in hot weather and when drilling at depths greater than 10,000 feet. One worker said that vapors will drive you out of the mudpit room under these conditions.

We had noticed that some of the roughnecks had cut off the long sleeves of their coveralls (supplied to them by their drilling contractor company). The men said that they were not required to wear long sleeves or safety glasses on the job. It was felt that floorhands should not have to work on hot days in long sleeves. The roughnecks felt that it was worth the scrubbing and possible skin irritation involved with skin contact with the oil base mud to be able to work in short sleeves.

This observation of a few hours was too short to draw any conclusions about actual hazards from contact with oil base mud. However, it does suggest that oil base mud should receive further attention during this project.



FIGURE K.32. CONTACT WITH OIL BASE MUD ON THE DRILL FLOOR

APPENDIX L

TASK IV OBSERVATION REPORT

TASK IV OBSERVATION REPORT

From 11/10 to 11/15/81, two SwRI engineers and the USCG project technical monitor took part in an observation of offshore drilling and production activities on platforms owned and operated by Company E. The observation was conducted on platforms A, C, D, and F in the field of five platforms shown schematically in Figure L.1. This figure also lists the major facilities that are located on each platform. Platform F, shown in Figure L.2, supported a drilling rig and the living quarters and galley facilities for the drilling crew. This platform had eleven wells, of which nine were connected to the production manifold, and was in the process of drilling a twelfth well during our observation.

Platform D, shown in Figure L.3, was connected to Platform F by a steel walkway. This platform contained producing wells, a water source well for water flooding, a water flood pump driven by a gas turbine engine, and the office and galley facilities for the production crews on platforms F, D, and C.

Platform C, shown in Figure L.4, was connected to Platform D by a steel walkway. This platform contained producing wells, a waterflood source well, and the oil, water and gas separation facilities used to treat production from platforms F, D, C, and E. This platform also contained two 1000 psi natural gas compressors. At the time of our visit, a well workover rig was located on platform C.

Platform E contains 3 producing wells and waterflood injection wells. It is accessible by crewboat from platform D. It was not visited by the Task IV observation team.

Platform A contains producing wells, oil, water, and gas separation facilities, a 2000 psi gas lift compressor, a 1000 psi sales compressor, an oil sales LACT and living, galley and office facilities for production crew. It is accessible either by helicopter or crewboat from other platforms in the field.

The observation team divided its time between platforms F, D, C, and A. Thus it was possible to perform a trial implementation of the experimental test plan for both offshore production and offshore drilling crews. The daily activities of the observation team are summarized in outline form below.

o 11/10

- Arrive at platform F.
- Tour platforms F, D, and C.
- Gather information on crew complement.
- Discuss project objectives with crew members and record their observations and experience.

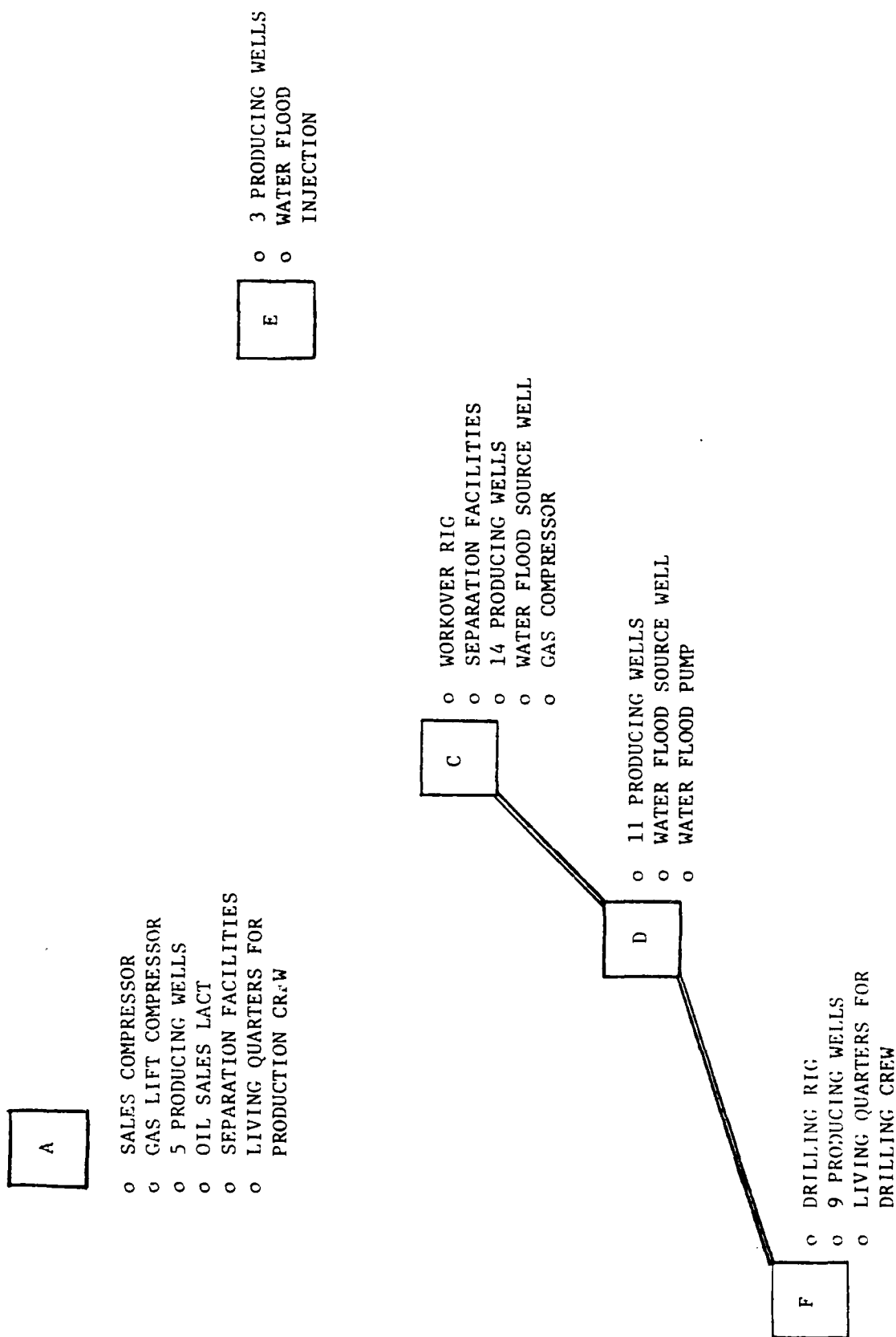


FIGURE L.1 ARRANGEMENT OF OFFSHORE PLATFORMS - TASK IV OBSERVATION



FIGURE L.2. PLATFORM F WITH DRILLING RIG

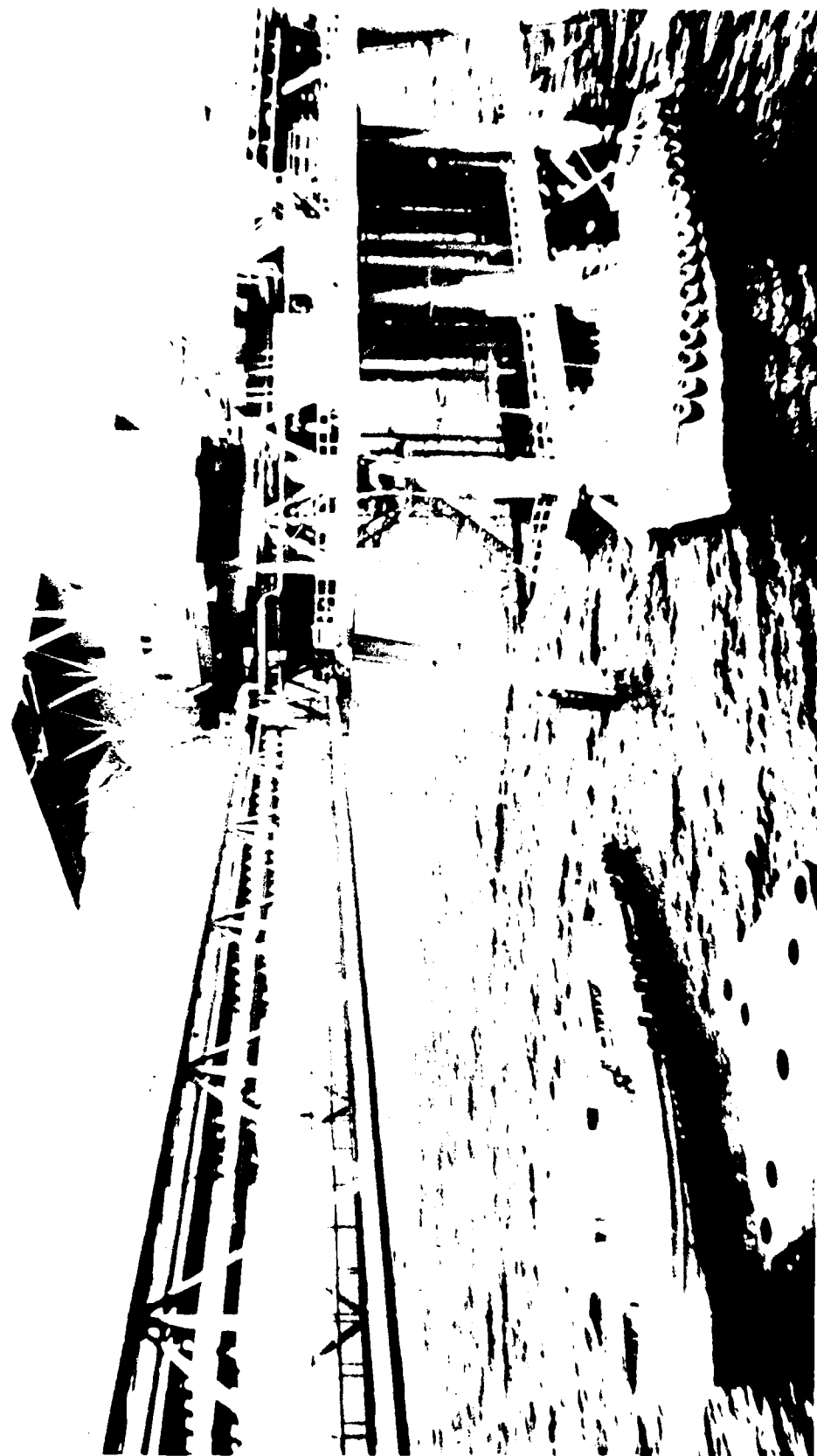


FIGURE L.3. PLATFORM D WITH CREW/SUPPLY BOATS

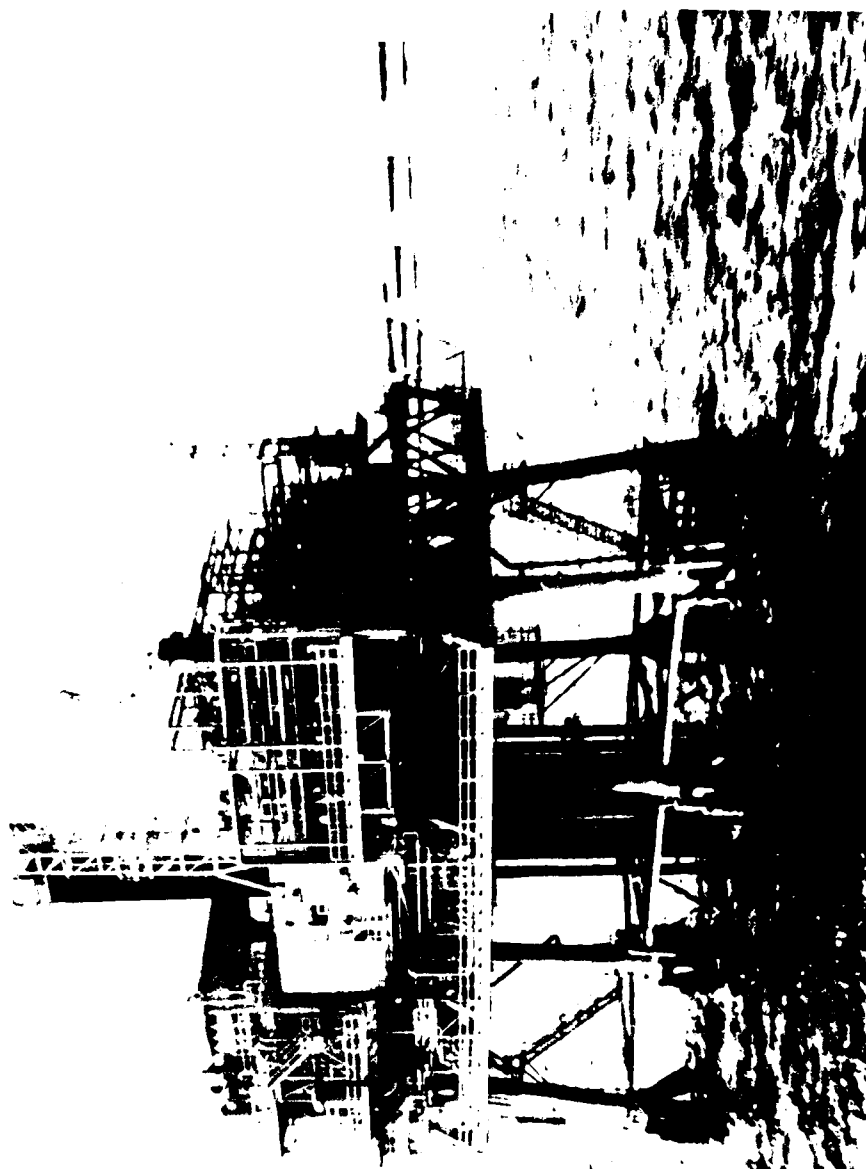


FIGURE L.4. PLATFORM C WITH WORKOVER RIG

- o 11/11
 - Perform an emission source survey of platforms F, D, and C using organic vapor analyzer in total hydrocarbon mode.
 - Identify emission sources and document concentration level.
- o 11/12
 - Obtain emission source samples from two flowing wells, flotation cell and compressor room on platform C.
 - Prepare dilute samples and perform a gas chromatograph (GC) analysis of emission source samples.
- o 11/13
 - Obtain and analyze additional source samples of demulsifier, flotation agent, methanol additive and a sample from gas production line on platform C.
 - Obtain and analyze area samples from compressor room on platform C for gas concentration.
 - Perform personal dust exposure sampling on mudman for a 12-hour shift on drilling rig (platform F). Observe and record activities of mudman that involve exposure to dust.
- o 11/14
 - Perform an emission source survey on platform A using organic vapor analyzer. Identify and document emission sources and concentration levels.
 - Obtain and analyze area samples in the vicinity of the flotation cell on platform C for gas concentration.
- o 11/15
 - Observe and record activities of mudman on platform F drilling rig for a 12-hour shift. Perform personal dust exposure sampling during periods of dust exposure.
 - Observe and record activities of driller, derrickman and roughnecks on the drilling floor. Note dermal exposure to drilling fluids.
- o 11/16
 - Brief the Company E observer on our activities and findings.
 - Return to shore.

Table L.1 lists the job titles, work schedules and numbers of people employed on the workover rig, the drilling rig and the lease production crew. Most of these personnel work 12-hour shifts for seven days on the job followed by seven days off the job. Many of the men live within a five-hour drive of their offshore departure station. However, a few live significantly greater distances away and drive for eight to ten hours between home and work. Drilling is generally an around-the-clock operation requiring day and night crews. However, maintenance services and production operations are routinely performed during day work. When necessary, the mechanic/electrician is requested to work overtime as required.

For the drilling crew, the worker who has the greatest potential for exposure to production gases, chemical dust, liquid chemicals, and drilling fluid is the roughneck/mudman. His duties include cleaning and servicing the shale shaker, shown in Figure L.5, where produced gas may be released from gas cut mud. The mudman routinely washes down the shale shaker with water to remove accumulated cuttings and changes screens as required if they become torn. When drilling through certain depths he may collect samples of the cuttings for inspection on shore by company geologists.

The mudman may contact the drilling fluid when he takes samples (shown in Figure L.6) for routine measurements of funnel viscosity and mud weight (shown in Figure L.7). During meal times he may be required to assist the drilling floor crew in adding new lengths of drill pipe (shown in Figure L.8). This operation may expose the roughnecks to drilling fluid splash.

On this drilling crew, the mudman was also responsible for adding bags of dry drilling fluid ingredients to the mud system through the hoppers above the mud pits (shown in Figure L.9). He also added liquid chemicals from 55-gallon drums as required by the mud program.

On 11/13 and 11/15, the activities of the mudmen were observed and recorded over 12-hour periods. Personal dust exposure sampling was performed both on the mudmen and on the USCG technical monitor acting as an observer (see Figure L.10).

Sampling for personal exposure to dust was accomplished using an MSA cyclone assembly with a 0.8 μ millipore MCE filter which was attached to the employee's lapel with an alligator clip. Air was drawn through the cyclone assembly by an MSA model S pump adjusted to give a volume flow rate of about 1.7 liters/minute with the cyclone assembly attached. The filter cartridges were returned to SwRI and weighed to determine the amount of dust of respirable size that was collected during the exposure period.

The observation on 11/13 spanned a shift change at about 5:00 P.M., so that the project team had the opportunity of watching two different individuals performing the same duties. Both men wore short-sleeve shirts

TABLE L.1 CREW COMPLEMENT - TASK IV OBSERVATION

WORKOVER RIG	Work Schedules		Number Per Shift		Notes
	7 on/7 off	5 on/2 off	Day	Night	
• Driller	✓		1	1	
• Derrickman	✓		1	1	
• Rotary Helpers	✓		2	2	
• Roustabouts	✓		3	2	
• Crane Operator	✓		1	1	
• Mechanic/Electrician	✓		1	1	Subject to overtime Available on call
• Fishing Tool Man	✓		1		
DRILLING RIG					
• Drilling Foreman (Toolpusher)	✓		1		
• Clerk	✓		1		Available on call
• Driller	✓		1	1	
• Derrickman	✓		1	1	
• Roughnecks - Rotary Helpers	✓		2	2	
• Roughneck - Mudman	✓		1	1	
• Roughneck - Trainee	✓		1	1	
• Motor man	✓		1	1	
• Mechanic/Electrician	✓		1	1	Subject to overtime
• Crane Operator	✓		1	1	
• Welder	✓		1	1	
• Roustabouts (contract)	✓		1	1	
• Cementer (contract)	✓		4	4	
• Directional Driller (contract)	✓		1		Available on call
• Mud Engineer	✓		1		Available on call
• Galley Staff (contract)	✓		1		Available on call
• Quarters personnel	✓		3	2	
PRODUCTION CREW					
• Lease Operator	✓		1		Available on call
• Helper C & D	✓		1		Available on call
• Helper A	✓		1		Available on call
• Mechanic	✓		1		
• Mechanics		✓	2		
• Automatic Control Man	✓		1		
• Automatic Control Man		✓	1		
• Electrician	✓		1		
• Meterman		✓	1		
• Roustabouts		✓	3		
• Roustabouts	✓		2		
• Painters (contract)	✓		2		
• Operator assistant/nightman	✓		1	1	When required Always on a platform during drilling for emergency well shut-in

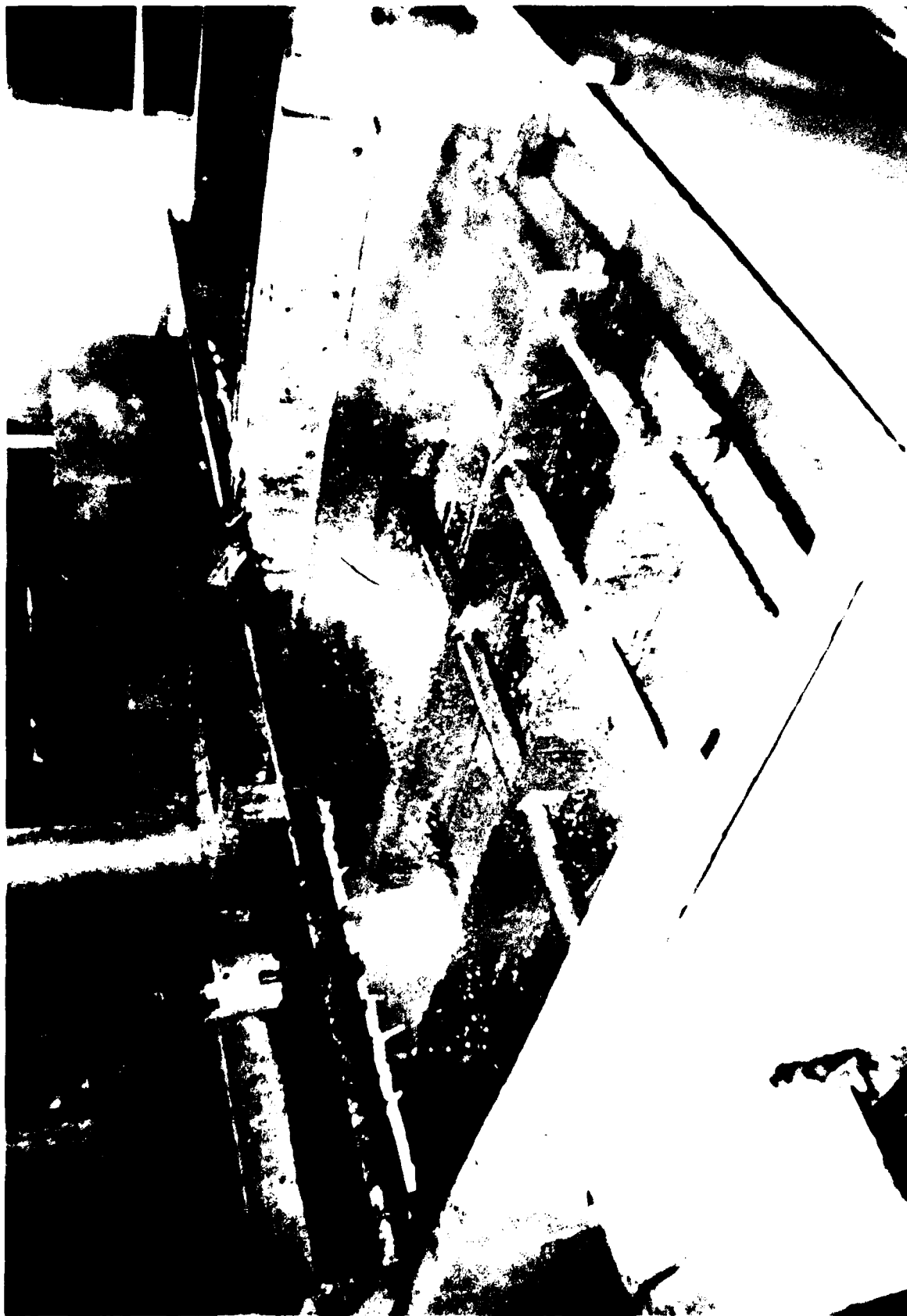


FIGURE L.5. SHALE SHAKER REMOVING CUTTINGS FROM WATER BASE MUD



FIGURE L.6. MUDMAN COLLECTING DRILLING FLUID SAMPLE FOR VISCOSITY MEASUREMENT



FIGURE L.7. MUDMAN MEASURING MUD WEIGHT

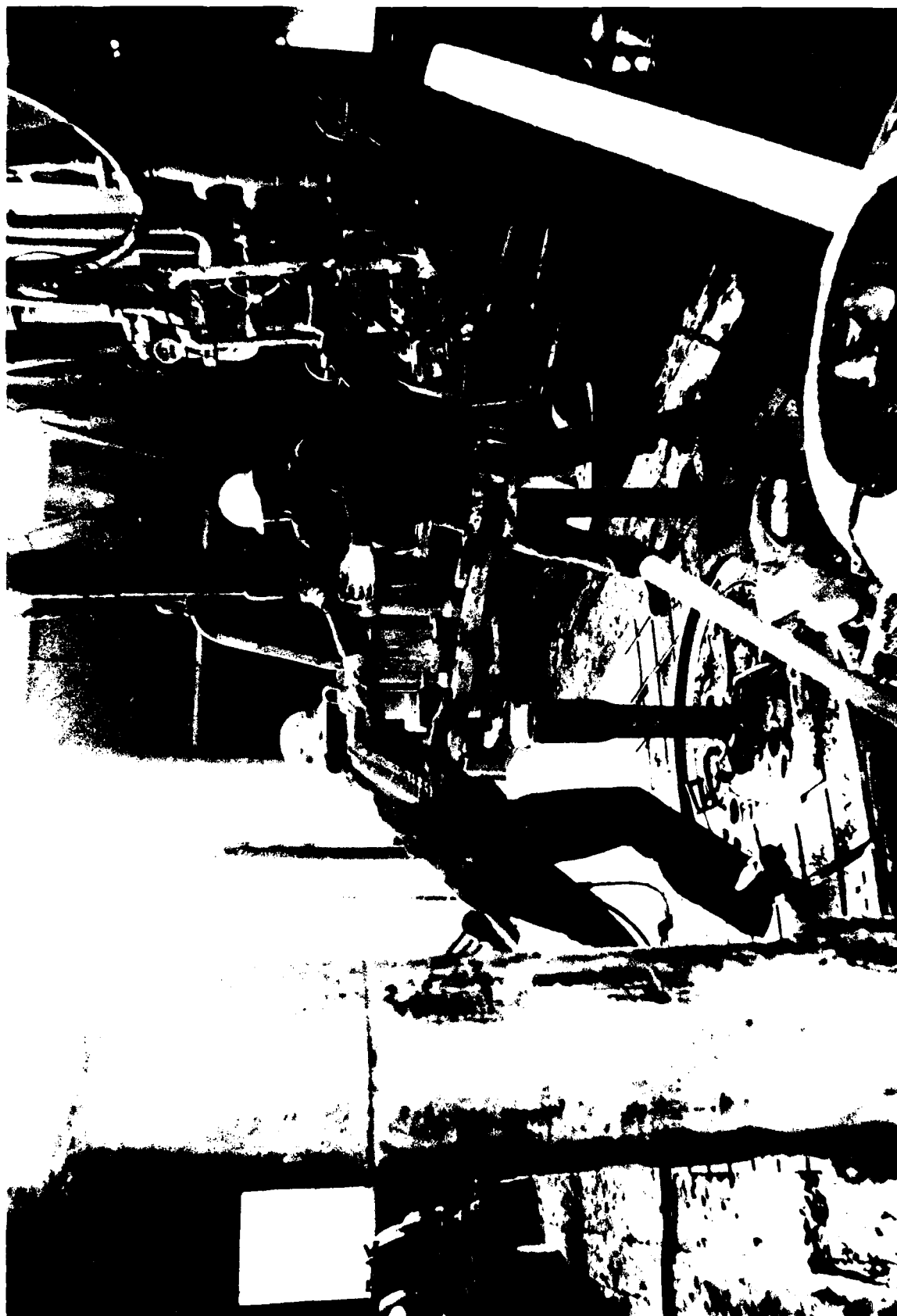


FIGURE L.8. MUDMAN ASSISTING DRILLING FLOOR CREW

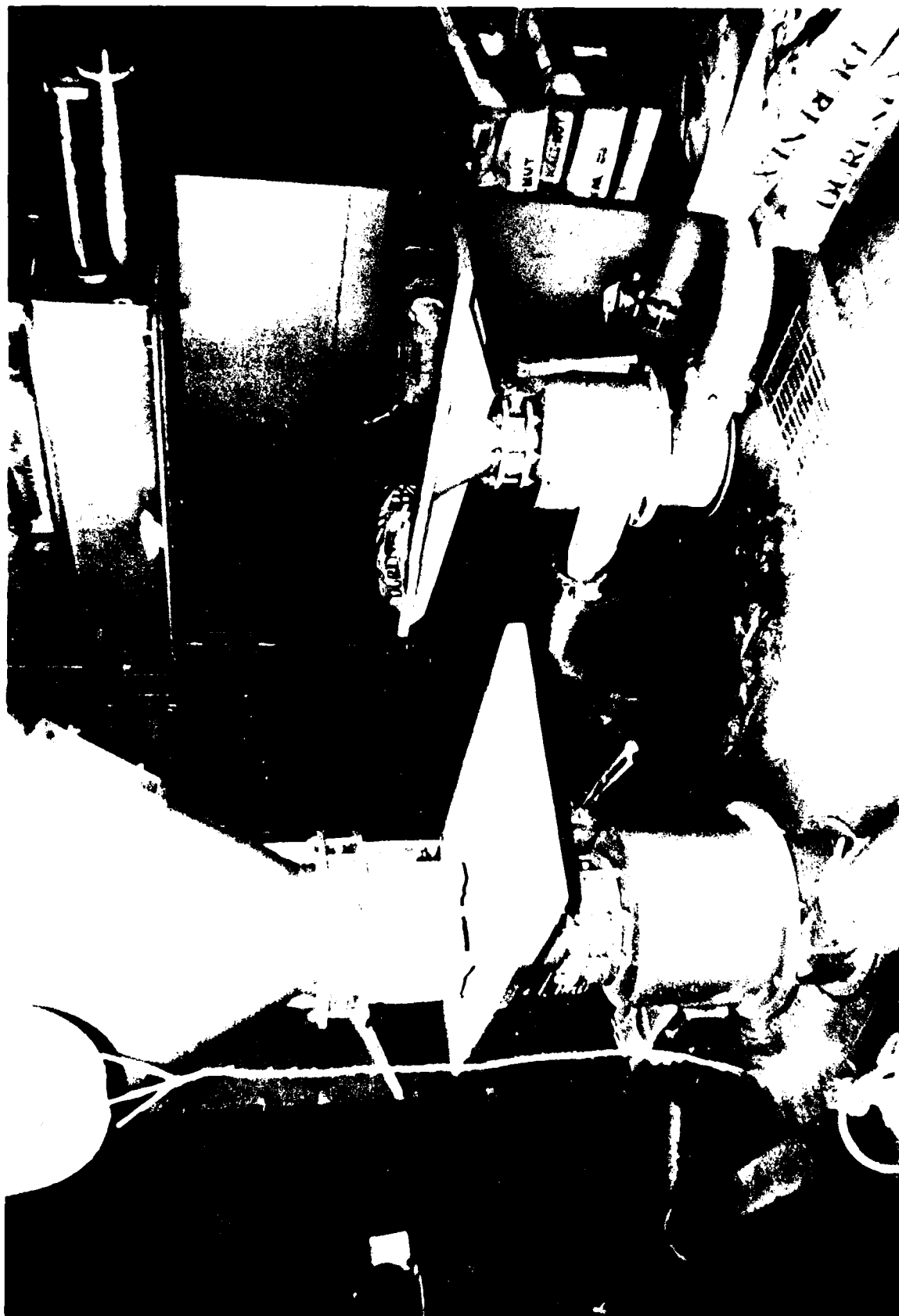


FIGURE L.9. DRY BULK HOPPERS IN MUD MAKE-UP ROOM

TABLE L.2. LIST OF DRILLING FLUID CHEMICALS STORED
FOR USE ON DRILLING RIG PLATFORM F

o Stored in Bags in Mud Make-Up Room

<u>Product Name</u>	<u>Description</u>
Aqua gel	bentonite clay
Black Magic	oil base mud concentrate
Calcium Carbonate	calcium carbonate
Carbonox	lignitic material
Caustic Soda	caustic soda (sodium hydroxide)
Drispac Regular	polyionic cellulose fluid loss additive
Drispac Superflo	polyionic cellulose fluid loss additive
Durenex	polymer fluid loss additive
Lignite	lignite
Metasap	(unknown)
Mica	mica flakes
Micatex	mica flakes
Q-Broxin	ferrochrome lignosulfonate
Sodium Chromate	sodium chromate
Wall-nut Medium	ground nut shells for fluid loss prevention

o Stored in Dry Bulk Tank

Barite	barium sulfate
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o Stored as Liquids in 55-Gal. Drums

Aluminum Stearate	aluminum stearate
Bara Defoam	surface active defoamer
Akta flo-S	nonionic mud surfactant



FIGURE L.10. PERSONAL DUST EXPOSURE SAMPLING DURING ADDITION
OF CHEMICALS TO DRILLING FLUID

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A CREW EXPOSURE STUDY VOLUME 1 OFFSHORE(U) SOUTHWEST
RESEARCH INST SAN ANTONIO TX ENGINEERING SCIENCES DIV
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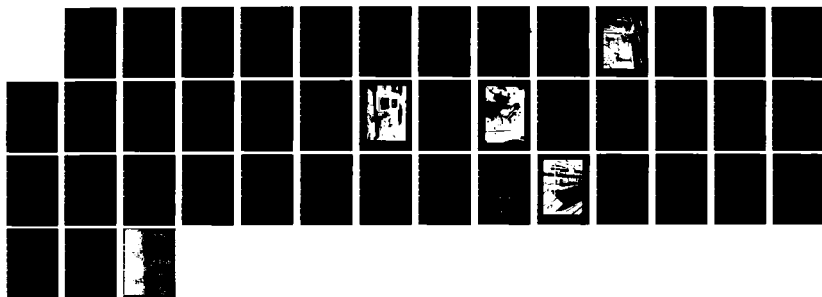
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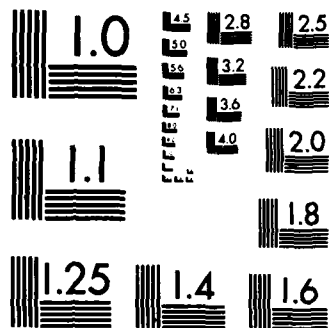
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

of coveralls, hard hats and a particle dust mask (3M No. 6983 for dust, TC-21C-132). Neither man wore gloves, and both removed the dust mask when not adding bags of chemical. During each 12-hour shift, the mudmen performed several activities in a routine manner. The most important were:

- o Measured weight and viscosity of the mud going to and coming from the hole every 30 minutes.
 - o Collected a sample of cuttings from the shale shaker every 30 feet of drilled hole.
 - o Measured a complete set of mud properties once per shift.
 - o Added barite from the bulk tank to the mud to maintain the mud weight specified by the mud program.
 - o Added liquid chemicals (aluminum stearate and a defoamer) to the mud.
 - o Added dry chemicals from bags
 - ferrochrome lignosulfonate
 - lignitic material
 - fluid loss additive
 - caustic soda
 - bentonite clay
 - ground walnut hulls
- on the recommendation of the mud engineer. A major treatment of 85 to 90 bags over two to three hours was performed about every 12 hours. Smaller additions were made to counteract drill pipe sticking from time to time.
- o Washed the shale shaker to remove accumulated cuttings.
 - o Washed the slugging pit.
 - o Assisted on the drill floor as needed.

The results of the dust sampling measurements on 11/13 are shown in Figure L.12 for both the mudman and the observer. Samples of 100 minute duration were collected during six sampling periods for the mudman, and five sampling periods for the observer. Table L.3 lists the primary activities of the mudman during each sampling period.

We observed that the mudman who went off duty at 1700 hours used a technique for slitting and emptying bags that tended to minimize the amount of airborne dust. The lignitic material and the ferrochrome lignosulfonate consisted of fine particulate matter, and they generated more dust than the other ingredients (for example, the walnut hulls are coarsely ground and generate little or no airborne dust). However, both men were careful to avoid contact with caustic soda. When performed carefully, the addition of barite did not generate much airborne dust. The project team observed that individual technique can have an effect on minimizing workplace dust concentrations.

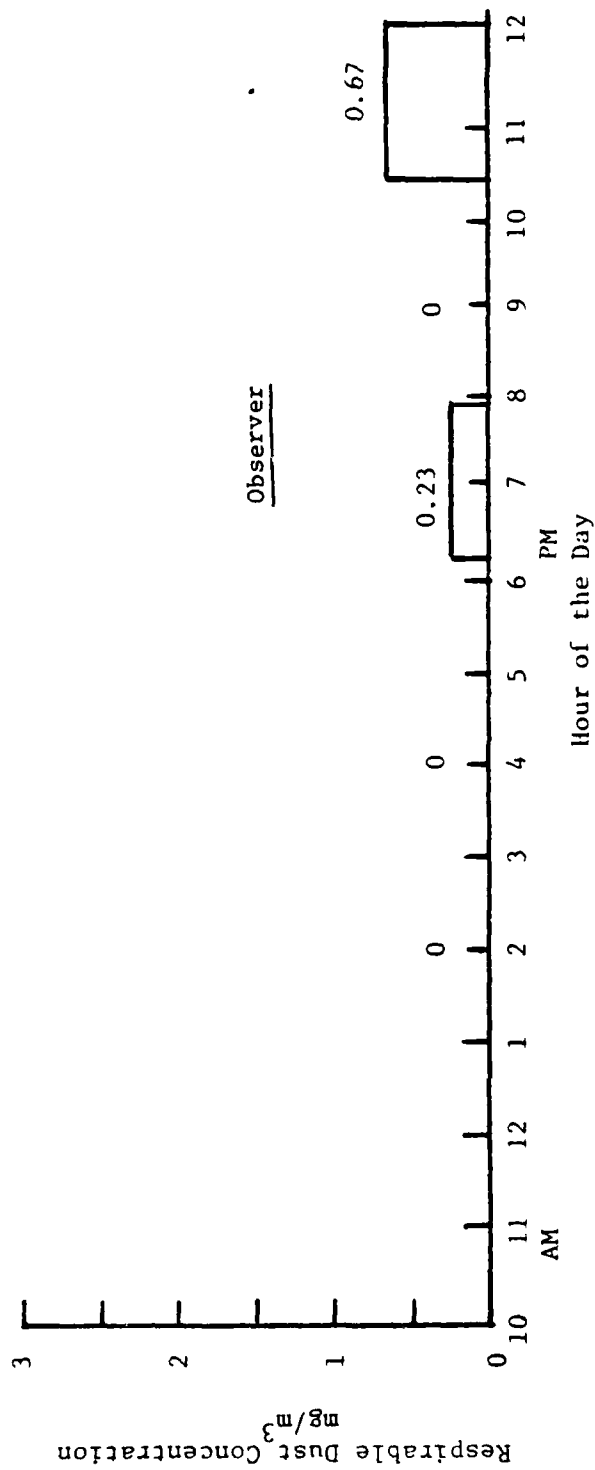
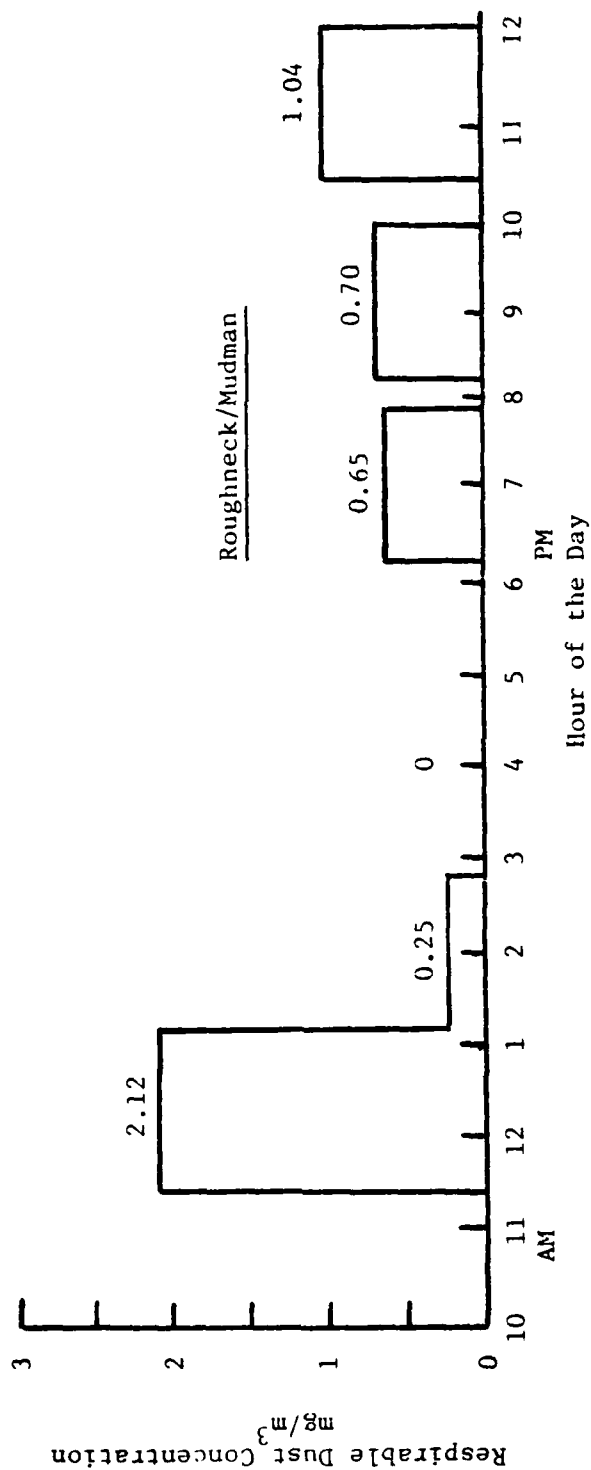


FIGURE L.11 RESULTS OF RESPIRABLE DUST CONCENTRATION MEASUREMENTS ON 11/13/81

TABLE L.3. ACTIVITIES OF MUDMAN DURING DUST SAMPLING PERIOD

Period	Time	Activity Involving Chemical Dusts
1	11:22 AM to 1:07 PM	Added barite from bulk tank and 78 bags of chemicals over ~ 51 minutes
2	1:09 PM to 2:49 PM	Added barite and 18 bags of chemicals over ~22 minutes.
3	3:06 PM to 4:46 PM	Added barite and 11 bags of chemicals over ~12 minutes.
4	6:13 PM to 7:53 PM	Added barite and 2 bags of chemicals over ~21 minutes.
5	8:12 PM to 9:52 PM	Added barite and 2 bags of chemicals over ~28 minutes
6	10:22 PM to 12:02 AM	Added barite and 11 bags of chemical over ~43 minutes.

Referring again to Figure L.11, it is noted that the measured dust concentrations for the observer are lower than for the mudman. This is as expected since the observer was careful not to get in the way of or interfere with the mudman during chemical addition. All concentrations are below the TWA-TLV of 5 mg/m^3 respirable dust for nuisance particulates. If the average dust concentration for each sampling period is divided by the fraction of time over which barite and other chemicals were added, the following estimates for respirable dust concentration during chemical addition are obtained.

Period	Respirable Dust Concentration
1	4.4 mg/m^3
2	1.1
3	0.0
4	3.1
5	2.5
6	2.4

On this basis it may be inferred that the respirable dust concentration during sustained periods of chemical addition is also below the 5 mg/m^3 TWA-TLV.

The observation on 11/15 ran from approximately 0600 hours to about 1700 hours. For part of this period, the mudman was assisted by a drilling floor roughneck. Both men wore particle dust masks during mud chemical addition. The activities of the mudman during his shift were the same as those observed on 11/13 with two exceptions. On 11/15, the mudman also performed minor maintenance on the desilter, operated the desander, and changed screens on the shale shaker.

Dust sampling was performed on the USCG observer while he followed the mudman and observed his activities. Samples of 100-minute duration were collected during three sampling periods. Table L.4 lists the primary activities of the mudman during each sampling period.

TABLE L.4. ACTIVITIES OF MUDMAN DURING DUST SAMPLING PERIOD

Period	Time	Activity Involving Chemical Dusts
1	8:20 AM to 10:08 AM	Added barite from the bulk tank and a few sacks of ground nutshell over ~10 minutes.
2	12:01 PM to 1:41 PM	Added barite and ~40 bags of chemicals over ~52 minutes.
3	2:00 PM to 3:43 PM	Added barite and sacks of chemicals over ~7 minutes. Major activity was changing screen on shale shaker.

The results of the dust sampling measurements on 11/15 are shown in Figure L.12. Dust concentrations equal to 0 mg/m^3 were measured for periods 1 and 3 when chemical addition activity was very low. During period 2 an average dust concentration of 1.05 mg/m^3 was measured. If this figure is divided by the fraction of time over which chemicals were added, we obtain an estimate of 2.1 mg/m^3 for respirable dust concentration during chemical addition. This estimate is entirely consistent with other estimates obtained on 11/13.

From these observations, we may make the following conclusions:

- o Dust levels associated with the addition of dry chemicals to the drilling fluid are below the TWA-TLV allowable limit of 5 mg/m^3 for nuisance particulate dust in the respirable size range.
- o Particulate dust masks used during mud chemical addition are effective in preventing irritation of nasal and throat passages by dust particles.

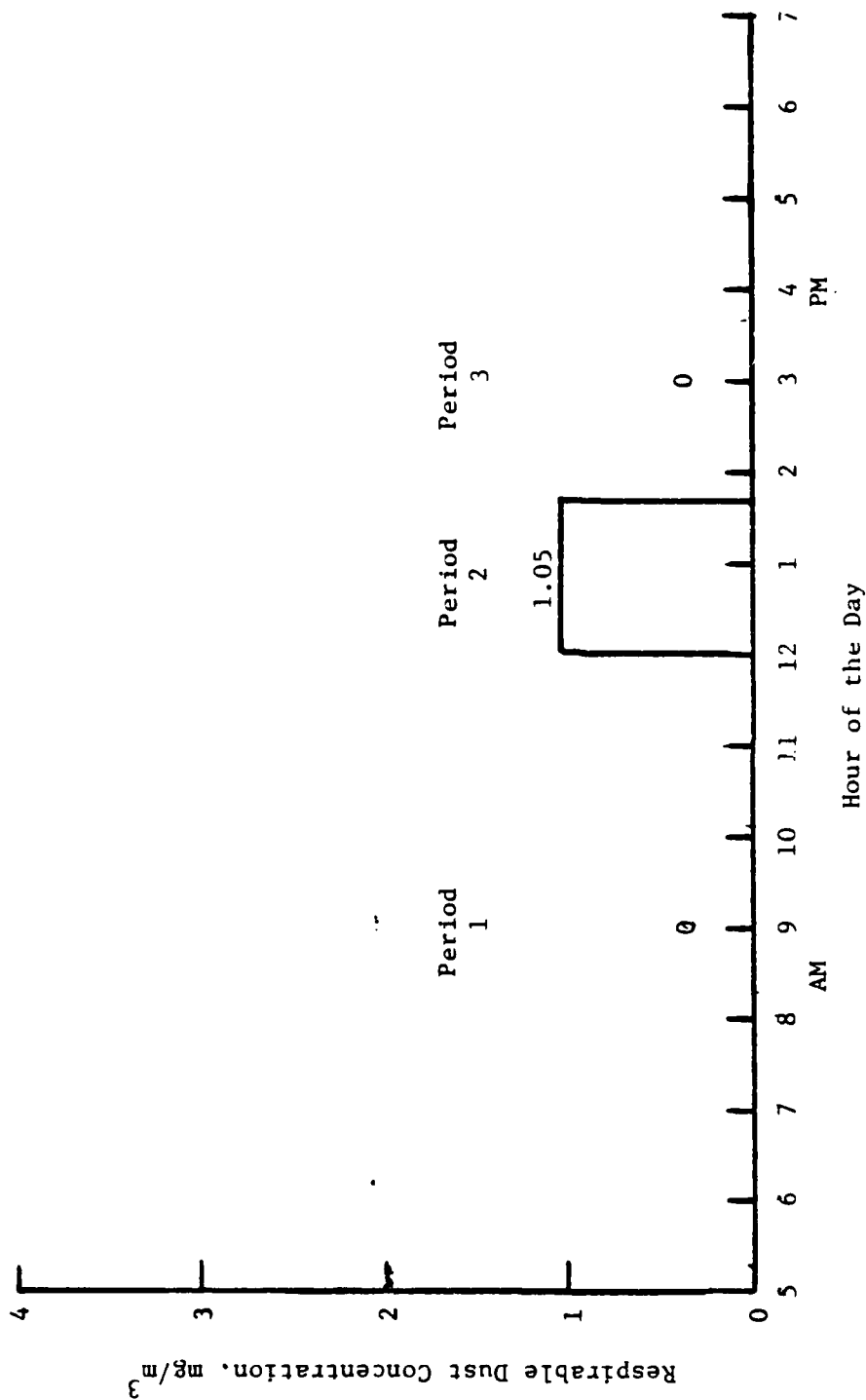


FIGURE L.12 RESULTS OF RESPIRABLE DUST CONCENTRATION MEASUREMENT ON 11/15/81
(OBSERVER FOLLOWED MUDMAN)

An opportunity to measure the mudman's exposure to formation gases and vapors did not arise during the observation. SwRI observers used the Organic Vapor Analyzer to measure hydrocarbon gas concentration levels near the shale shaker on 11/11 during the walk-through survey. Gas and vapor concentrations ranging from 5 ppm to 10 ppm as methane were measured at typical work locations for a mudman washing the shale shaker. Right above the shale shaker screen the maximum reading was about 30 ppm. These measurements were repeated at 11/13 during the observation of mudman activities. On this occasion, the maximum concentration above the shale shaker screen was about 70 ppm. A reading of 40 ppm was obtained above the mud surface near the gas detector. Away from the gas detector readings of 70 ppm to 160 ppm were obtained above the mud surface. On this rig, the shale shaker is located outside the mud storage building. Canvas tarpaulins provide wind protection, but the air circulation flow past the shale shaker was good enough to dilute the gases evolved from the mud.

Our observations of the mudmen did not indicate unusual or prolonged skin contact with the drilling fluid. Most skin contact with mud occurred when samples were taken for viscosity and density measurements. Exposure time was minimal as the mudman washed his hands and arms under the water faucet in the mud lab after contacting the drilling fluid. We discussed the subject of skin irritation and burns from contact with drilling fluids with the mudmen, with service company mud engineers, and with the driller on the workover rig. They volunteered the following information.

- o Completion fluids such as calcium chloride and calcium bromide will not cause problems through skin absorption. However, they will enter a wound and cause it to become inflamed. If calcium bromide enters a cut at the start of the week, it can cause a problem by the end of the week.
- o Calcium chloride and calcium bromide are delivered to the rig premixed in tanks. Mudmen will wear goggles and an apron when working with these materials.
- o Caustic (sodium hydroxide) is the main problem for burns. Most skin contact problems are associated with caustic and calcium bromide.
- o The mudmen had not personally had any skin irritation from either oil base or water base muds. One mudman had worked on a rig (for another employer) that used an invert emulsion oil base mud. He recalled using diesel fuel to remove the mud from his hands and skin. He found it hard to remove oil base mud from clothing with soap and water. Water would not wash the oil base mud away from the drilling rig floor; it skimmed right over the top of the mud.
- o The mud engineers also had experience with oil muds. Diesel fuel is used as the oil base; few still use lease crude oil for a base. There are usually few complaints about vapors from the diesel fuel. Lime is often added to promote the pH.

The same degreaser soap solution that is used in the cuttings washer can be used to clean clothes. One engineer had heard of some irritation from oil base mud caused by a reaction to the diesel oil base. Ground nut shells can be thrown onto the rig floor to soak up the oil base mud splatter, then shoveled away.

The project team observed that the mudmen were careful when adding caustic (on this rig, the caustic is in the form of beads, not powder, and appeared to form no airborne dust that we could observe) to the hopper so as to avoid getting the caustic on their hands and arms. Generally, caustic was added slowly, trickling into the hopper, rather than quickly, as was the practice for other chemicals. The SwRI project team observed drilling activities on the rig floor on 11/13. These activities consisted of:

- o performing a directional survey and recovering the survey tool on a wireline.
- o drilling continuously from about 6:30 AM through the end of the observation at 5:00 PM.
- o checking the operation of the mud gas detector and other alarm systems.
- o making adjustments to the brake on the drawworks.
- o performing minor repairs to the tongs.

We were particularly interested in the events that occur when a new length of pipe is added to the drill string, and in observing whether any skin contact with drilling fluid occurs. The sequence of events is the same after every 30 feet of drilling, and is outlined in Table L.5.

The drilling crew consisted of a driller, a derrickman, two roughnecks and the mudman. The driller controls the operation of the mud pumps, the rotary table, and regulates the weight on the drill bit from the driller's console. The roughnecks, the mudman, and the derrickman wore cotton gloves, long-sleeve shirts, boots, hard hats, and coveralls. The mudman had rolled his sleeves to 2/3 length, exposing about 7" of forearm between glove and sleeve. Their clothes were clean, and free of mud when drilling was resumed after completing the directional survey.

The standard of cleanliness on this rig was high. Trash was collected and deposited in waste bins. The roughnecks used a creme hand cleanser to remove mud, dirt or grease from their hands when needed. After each new length of drill pipe was added to the drill string, the rig floor was hosed down with water. Excess water was "squeegeed" away towards the drains.

On only one occasion did we observe a significant loss of drilling fluid when the kelly was disconnected from the drillpipe. The photograph in Figure L.13 shows this event. Mud splashed out at the drill pipe

TABLE L.5. ADDING PIPE TO THE DRILL STRING

- (1) The driller stops the rotary table and shuts down the mud pumps.
- (2) The driller raises the kelly and the last string of pipe above the drill floor.
- (3) The driller lowers the drill string and kelly. Mud is prevented from rising in the drill string by a check valve.
- (4) The driller raises the kelly above the floor again until the junction with the last length of drill pipe is positioned about 1 meter above the rotary table. A roughneck rinses the outside of the kelly and the pipe with water from a hose.
- (5) A roughneck clamps the drillpipe in the rotary table with the slip and attaches the pipe tongs. The tongs are used to loosen the threaded connection between kelly and drill pipe.
- (6) The driller rotates the kelly to release the kelly from the last length of drill pipe. If mud is trapped inside the kelly, it may flow out onto the floor at this step.
- (7) The roughnecks move the kelly over to make-up to a new length of pipe in the rathole.
- (8) The driller raises the kelly and the new length of pipe vertically. The roughnecks catch the free end of the pipe and mate it to the pipe in the hole. The tongs are used to tighten the threaded connection.
- (9) The roughnecks remove the slip from the rotary table. The driller lowers the drill string into the hole. The kelly stabber mates to the rotary table.
- (10) The roughnecks wash down the tongs and the drill floor with water as drilling is resumed.



FIGURE L.13. DRILLING FLUID SPLASH FROM KELLY AND DRILL PIPE PRIOR TO ADDING A NEW JOINT OF PIPE TO DRILL STRING

connection onto the rig floor. The flow of mud lasted for only a few seconds. One roughneck, who was helping to break the kelly/drillpipe connections with the tongs, was splashed lightly with mud. He continued to work and cleaned up a few minutes later when drilling was resumed.

Therefore, our observation of the rig floor crew did not indicate any unusual or prolonged contact with drilling fluid. We discussed the subject of skin irritation from contact with the drilling fluid with the rig floor crew. None of them had experienced skin irritation from contact with drilling fluids.

Two rig crew members did mention that they thought that the noise level on the rig floor was high. The driller said that he always wears E.A.R. foam type plugs in his ears during his 12-hour shift. One of the roughnecks said that the squeal from the drawworks brake is loud, and nearly continuous at high drilling rates. We noted that the driller was the only crew member who wore ear plugs while working on the rig floor during our observation.

Contaminant emission source surveys were performed also for the oil and gas production facilities on platforms A, C, D and F. Hydrocarbon gas and vapor measurements at the emission sources were made using a Century Organic Vapor Analyzer (OVA) Model 128 in the total hydrocarbon mode. This instrument indicates the concentration of organic vapors as an equivalent concentration of methane over three linear ranges, 0 to 10 ppm, 0 to 100 ppm, and 0 to 1000 ppm. A reading of 1000 ppm is the maximum possible with this instrument. When an emission source gives a reading that is off-scale, it is necessary to dilute a sample of the contaminant gas stream with a known volume of ambient air to obtain a true measurement of gas or vapor concentration. Since the purpose of the walk-through survey was to identify contaminant emission sources rapidly, a reading of >1000 ppm was recorded whenever a reading was off-scale. Source sampling and analysis were performed later for several emission sources that gave off-scale readings.

The results of the emission source survey are shown in Table L.6 for platform A. Low flowrate, fugitive emissions were found from valves on Christmas trees of flowing wells, from around the inspection panel gaskets on the flotation cell, and from flanges and pipe connections in the gas transfer piping. Emissions from these sources were diluted by ambient air fairly rapidly in the downwind direction. Table L.6 shows that the measured background concentration level in the well head area was only 25 to 50 ppm, despite the presence of four emission sources with source concentration readings that exceeded 1000 ppm.

The most significant source of contaminant emissions on platform A was the oil transfer pump. Our walk-through survey took us through the electrical power generating room shown in Figure L.14. We were surprised to find that the gas concentration level increased as we approached an open doorway leading out of the room. When we used the OVA to follow the gas stream in the upwind direction, we were lead directly to the oil

TABLE L.6

GAS CONCENTRATIONS ON OFFSHORE PLATFORMS

COMPANY: E
 PLATFORM: A
 DATE: 11/14/81

<u>AREA/EQUIPMENT</u>	<u>GAS CONCENTRATION</u> <u>ppm (total) : methane)</u>
<u>Well Head Area</u>	
o A-15, from 3/4" valve on well head, bubbles of gas appear through oil residue	400 ppm to > ppm
o A-8, from 3/4" valve at top of well head	>1000 ppm
o A-9, leak from valve stem , leak at Cameron-Acme connection	>1000 ppm >1000 ppm
o A-10, several small leaks , top of Christmas tree	100 to 200 ppm 1000 ppm
o Background concentration: - in well head area - around well A-10	25 ppm 50 ppm
<u>Flotation Cell</u>	
o At edge of roof panel gasket	>1000 ppm
<u>Pipefitter's Room</u>	
o Background concentration level	15 ppm
<u>Generator Room (see Figure L.14)</u>	
o At control panel	100 to 140 ppm
o Between engines	250 ppm
o Near open doorway, downwind of oil transfer pump	400 to 700 ppm
(Continued on next page)	

TABLE L.6 (CONTD)

GAS CONCENTRATIONS ON OFFSHORE PLATFORMS

COMPANY:	E
PLATFORM:	A
DATE:	11/14/81
<hr/>	
<u>AREA/EQUIPMENT</u>	<u>GAS CONCENTRATION ppm (total as methane)</u>
<u>Oil Transfer Pump (see Figure L.14)</u>	
o Localized source (could not be identified)	>1000 ppm
o Background, downwind of pump	400 ppm to >1000 ppm
<u>Glycol Reboiler</u>	
o Sump vent	>1000 ppm
<u>1000 psi Gas Compressor Room (see Figure L.15)</u>	
o At control panel	100 ppm
o Along upper level walkway	200 ppm to >1000 ppm
<u>2000 psi Gas Compressor (on skid outdoors)</u>	
o Localized readings	<100 ppm
o Background concentration level	5 to 10 ppm
<u>Gas Sales Building</u>	
o Background concentration level	50 to 80 ppm
<u>Gas Transfer Piping</u>	
o Localized sources	>1000 ppm
o Downwind concentration	200 to 700 ppm at 5 ft from source
<u>Crane Shed (storage for belts and drums)</u>	
o Background	25 ppm

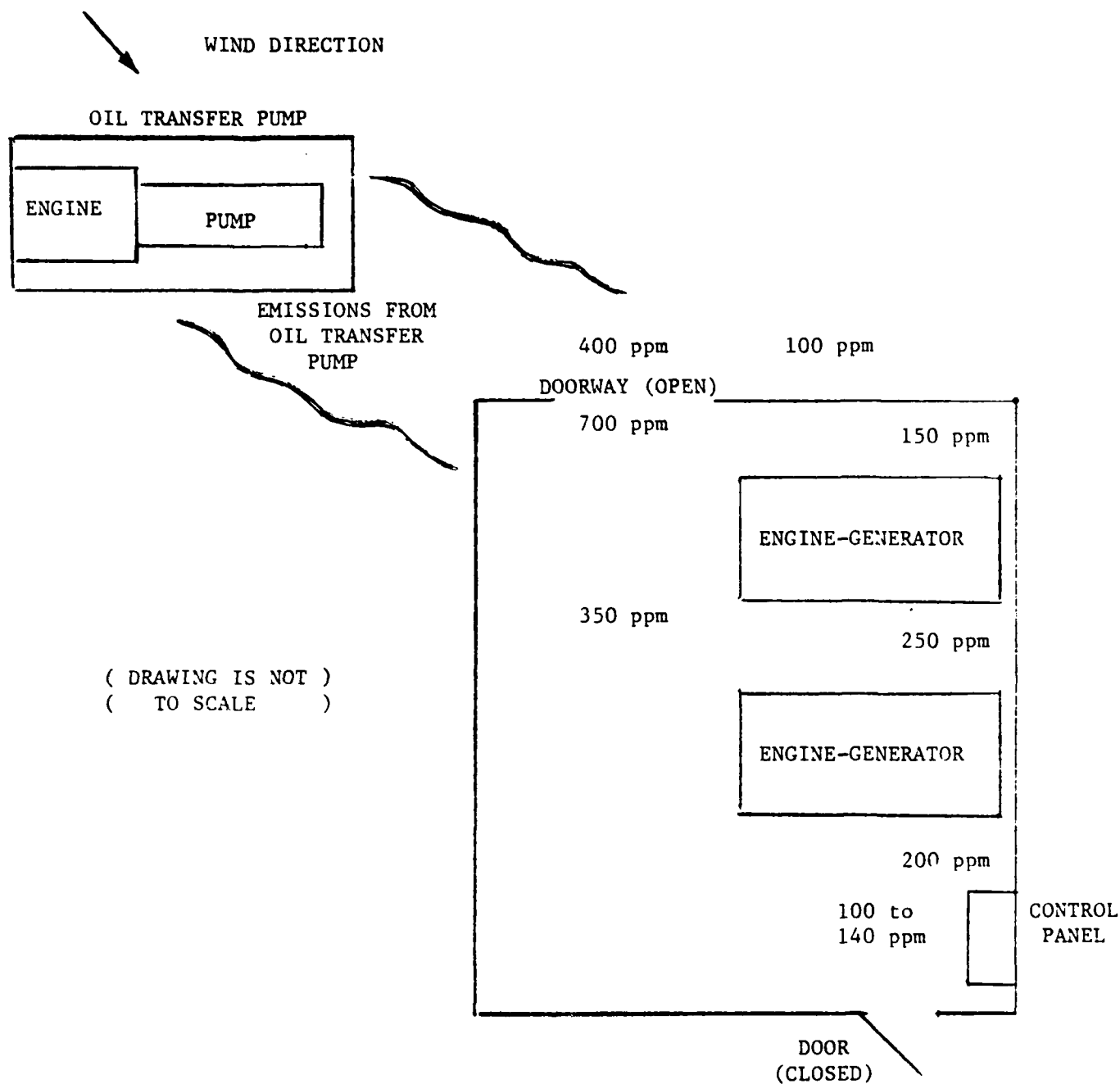


FIGURE L.14. VARIATION OF TOTAL HYDROCARBON CONCENTRATION
WITHIN GENERATOR ROOM ON PLATFORM A

transfer pump. The pump was not operating at the start of our survey, but gas and vapor emissions appeared to be coming from both the fuel (natural) gas driven engine and the crude oil transfer pump. It was difficult to identify the exact location of the emission source or sources since the OVA concentration reading would go off-scale when the sensing head was brought within 1 meter of the gas engine. We fitted a diluter to the sensing head which mixes the gas stream drawn through the sensor head with a second stream of ambient air drawn through a charcoal filter to remove contaminants. However, the OVA readings again went off-scale from contaminants drawn through the dilution leg.

The charcoal filter in the diluter removes most organic vapors from the ambient air stream, but it does not remove hydrocarbon gases such as methane and ethane. The fact that the OVA readings quickly went off-scale while using a diluter confirms that natural gas, with a large percentage of methane, ethane and propane, was the contaminant gas being emitted from the gas engine during our survey.

Our next step was to fill a bag with uncontaminated air obtained at a platform location that was upwind of the gas engine. The fresh air bag was then attached directly to the diluter. This procedure made it possible to search for the location of the gas emission source. We discovered a peak reading at a point on the front of the engine (near the radiator) where a water leak from the engine block had discolored the paint. The leak did not originate at a fuel gas line or coupling. Instead, it appeared that the gas was leaking into the water coolant in the engine block and escaping through the water circulation line.

We brought these findings to the attention of the lease operator in charge of production and the observer from the operating company. We spoke with a maintenance man who was familiar with the operation of the fuel gas engine and oil transfer pump. He was skeptical that fuel gas could be coming from a leak in the engine cooling system, and suggested that we were sensing glycol which was added as an anti-freeze solution. He said that they had been having problems with the gas engine and that it was hard to start. We confirmed that glycol vapor could be sensed by the OVA by obtaining a reading at the glycol reboiler (see Table L.6). However, glycol vapor will not pass through the charcoal filter on the diluter. Also, emissions of glycol vapor from a glycol vapor and water solution would not be high enough to produce the extensive gas cloud that was observed around the fuel gas engine.

The maintenance man started the engine and pump for us. With the pump operating, we found emissions of crude oil vapor from several sources, all small in size. We believe that the major source of emissions is from a leak at the front of the fuel gas engine, most probably from a point where cooling water leakage had been observed.

Contaminant emissions were relatively low on other parts of the platform as shown in Table L.6. We performed a thorough survey of the 1000 psi gas compressor room. Figure L.15 shows that gas concentrations in the room were in the range of 100 to 300 ppm, except along the walkway

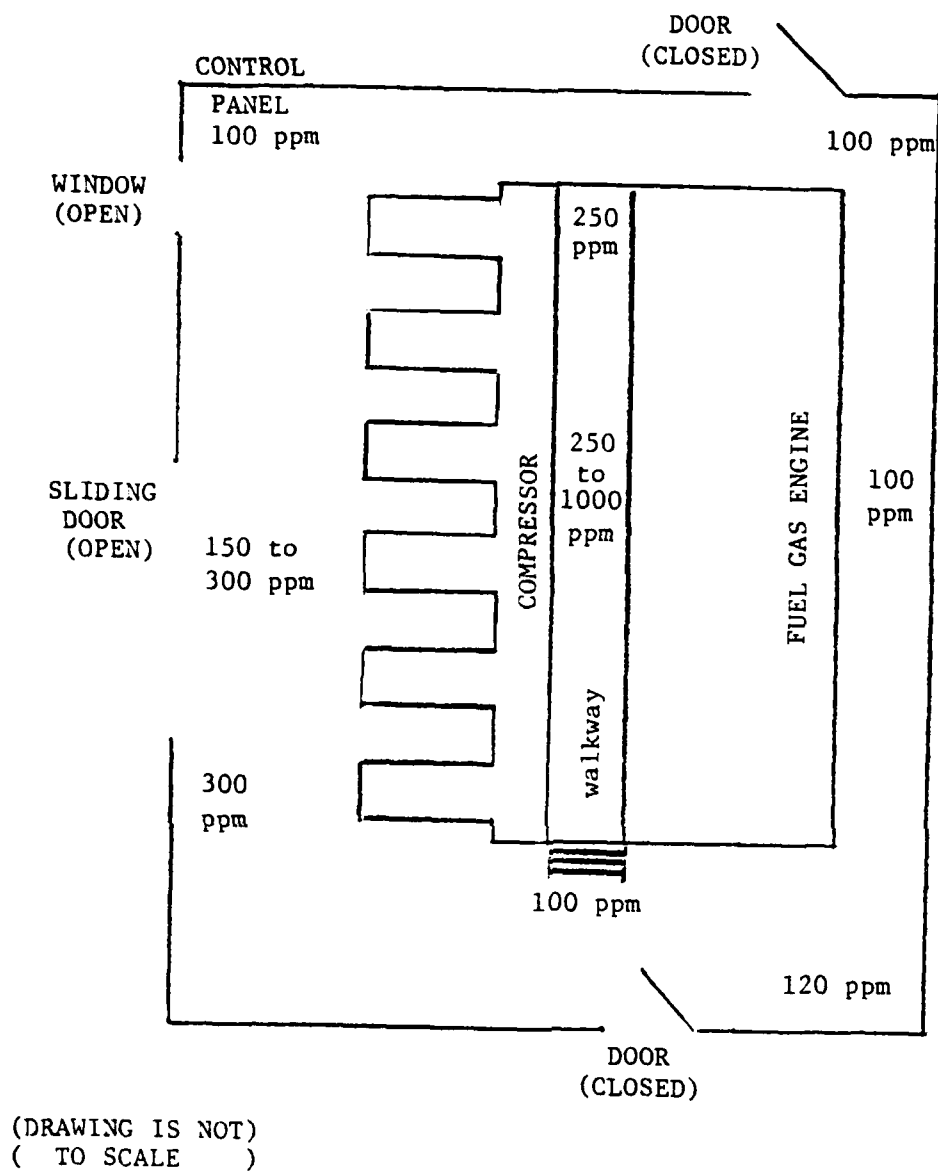


FIGURE L.15. VARIATION OF TOTAL HYDROCARBON CONCENTRATION
WITHIN 1000 psi COMPRESSOR ROOM ON PLATFORM A

above the compressor, where higher readings of 250 to 1000 ppm were found.

Table L.7 shows the results of the emission source survey for platform C. As for platform A, several fugitive emission sources were identified in the well head area. However, the background concentration level downwind of the well head Christmas trees ranged from about 40 to 80 ppm. Fugitive emissions were also found at gas line connections to flow meters (see Figure L.16) and from the stem of a control valve. The most significant findings on platform C were the emissions from the flotation cell, and the gas concentration levels in the compressor room.

The flotation cell is a device used to separate oil from produced water. On this platform, gas is removed from the liquid stream (containing oil and water) in the high pressure separator. The liquid stream passes into the free water knockout (FWKO) in which oil is allowed to float to the top of the water and separate by gravity. Water from the FWKO passes through a corrugated plate interceptor (CPI) which removes more oil. Water from the CPI flows into the flotation cell. A demulsifier and a flotation agent are added to assist in separating oil and water. Fuel gas bubbles up through the water to catch the oil residue and float it to the surface. Oil floating on the surface of the water is skimmed off and transported to the wet oil tank for more processing.

We first noticed the emissions from the flotation cell while standing about 5 meters downwind to watch the filling of the brine tank on the workover rig. The flotation cell has several roof panels which can be raised for inspection and maintenance. We noted that the gasket beneath one side of one roof panel was missing. This allowed the fuel gas blanket (added at a pressure of 2 oz/in²) to escape through the gap left by the missing length of gasket. The gas concentration was too rich to measure with the OVA (it put the flame out) without dilution.

The results of the emission source survey inside the fuel compressor room are shown in Figure L.17. Fuel gas leaks were found at the gasket on the compressor discharge heads as shown in Figure L.18. The locations of these leaks were marked by the observer from the operating company for inspection and repair. The concentration levels in the compressor room on platform D were somewhat higher than those in the compressor room on platform A. This is not surprising since the rate of emission of gas into each room and the ventilation airflow patterns are certain to be different.

Table L.8 shows the results of the emission source survey for platform D. The results are very similar to those found on platforms A and C. There were no emission sources that appeared to be releasing significant quantities of gas or vapor into the air.

Table L.9 shows the results of the emission source survey for platform F. A trash can compactor seemed to be an unusual source for vapor emissions until we found uncapped paint cans inside. The measurement of gas at the shale shaker have already been mentioned in the discussion of drilling rig activities. Figure L.19 shows that the level of gas escaping

TABLE L.7

GAS CONCENTRATIONS ON OFFSHORE PLATFORMS

COMPANY: E
 PLATFORM: C
 DATE: 11/11/81

<u>AREA/EQUIPMENT</u>	<u>GAS CONCENTRATION ppm (total as methane)</u>
<u>Well Head Area</u>	
o C-16, Around Christmas tree	100 to 300 ppm
o C-6, Rubber packing extruded around flange and gas escaping	> 1000 ppm
o C-14, Around valves	20 to 40 ppm average, but 300 to 400 ppm peak
o C-1A Around packing and flange	50 to 60 ppm, peak 100 ppm
o C-10, Leak from crack in packing around flange in gas lift line	> 1000 ppm
o C-7, on top of Christmas tree	> 1000 ppm
o C-13, Well is not flowing, but needle pegs near packing beneath union on the adjustable choke	> 1000 ppm
o Downwind of well head area, in front of radiator	40 to 50 ppm average, 80 ppm peak
<u>Gas Metering Run</u>	
o Line from orifice plate to meter	20 to 40 ppm
o Line into regulator behind gas meter	> 1000 ppm
o Leak at stem of Fisher control valve in 2000 psi gas lift line	> 1000 ppm

(Continued on next page)

TABLE L.7 (CONTD)

GAS CONCENTRATIONS ON OFFSHORE PLATFORMS

COMPANY: E
PLATFORM: C
DATE: 11/11/81

<u>AREA/EQUIPMENT</u>	<u>GAS CONCENTRATION</u> <u>ppm (total as methane)</u>
<u>Flotation Cell</u>	
o Missing gasket beneath roof panel	>1000 ppm
<u>1000 Psi Gas Compressor Room (see Figure L.17)</u>	
o At control panel	700 ppm
o Along upper level walkway	>1000 ppm

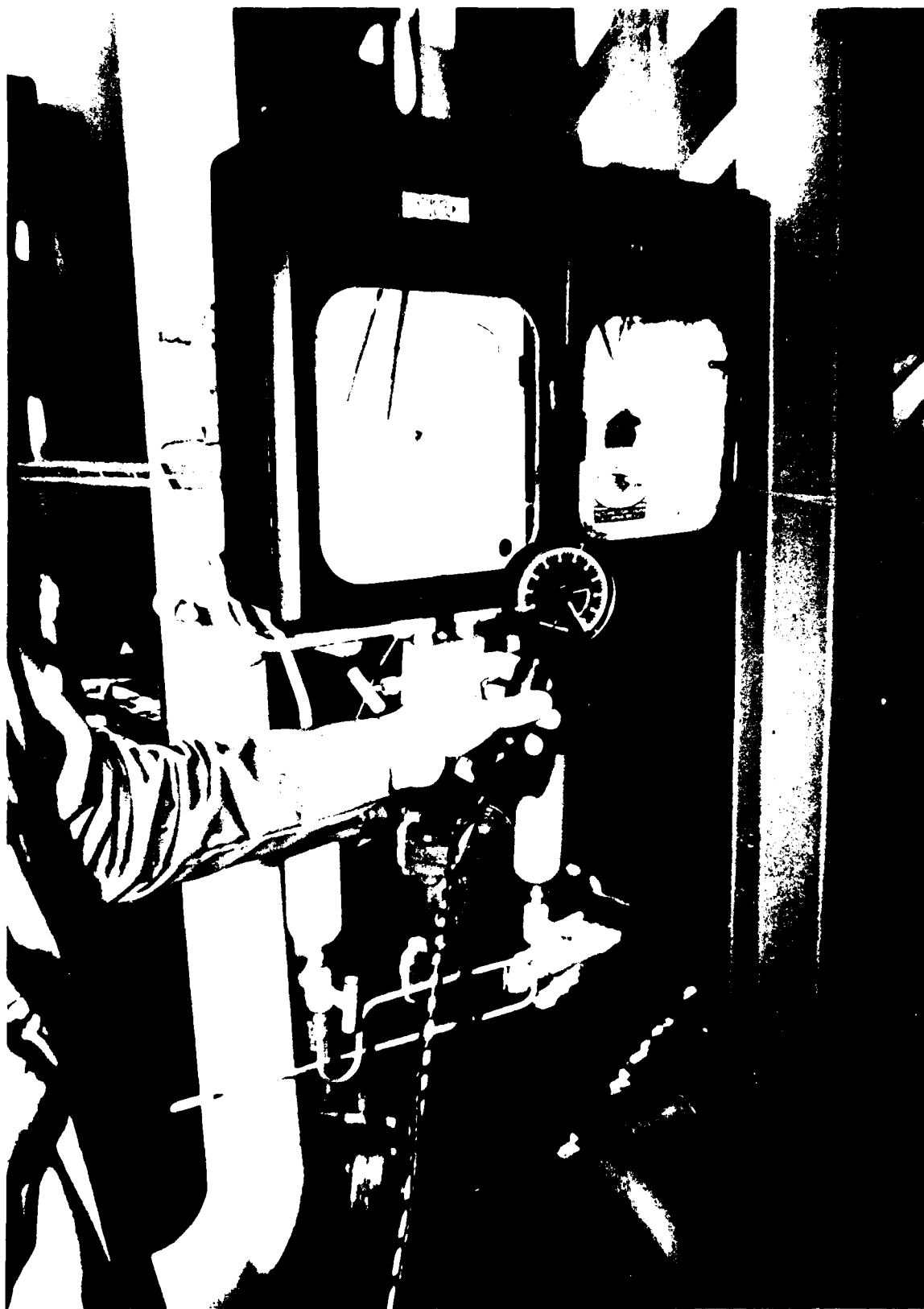
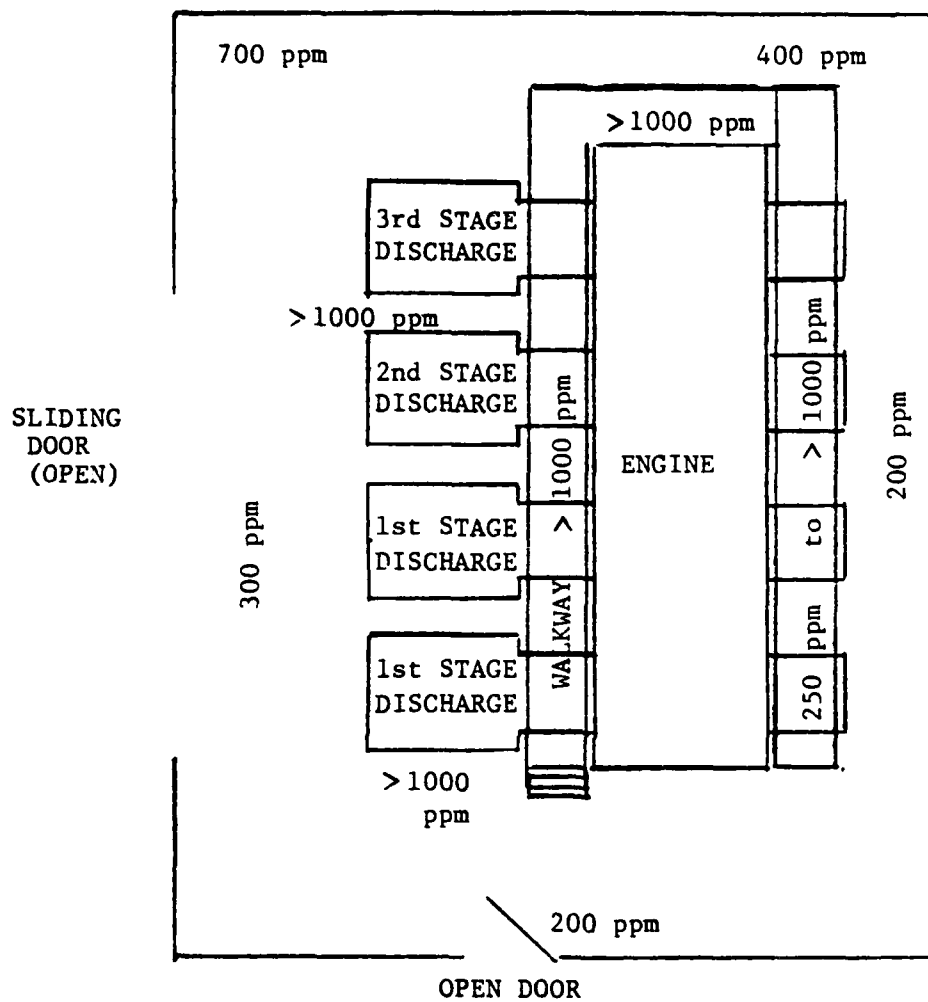


FIGURE L.16. FUGITIVE EMISSIONS FROM LEAK
AT GAS METERING CONNECTIONS



(DRAWING IS NOT)
(TO SCALE)

FIGURE L.17. VARIATION OF TOTAL HYDROCARBON CONCENTRATION
WITHIN 1000 psi COMPRESSOR ROOM ON PLATFORM C

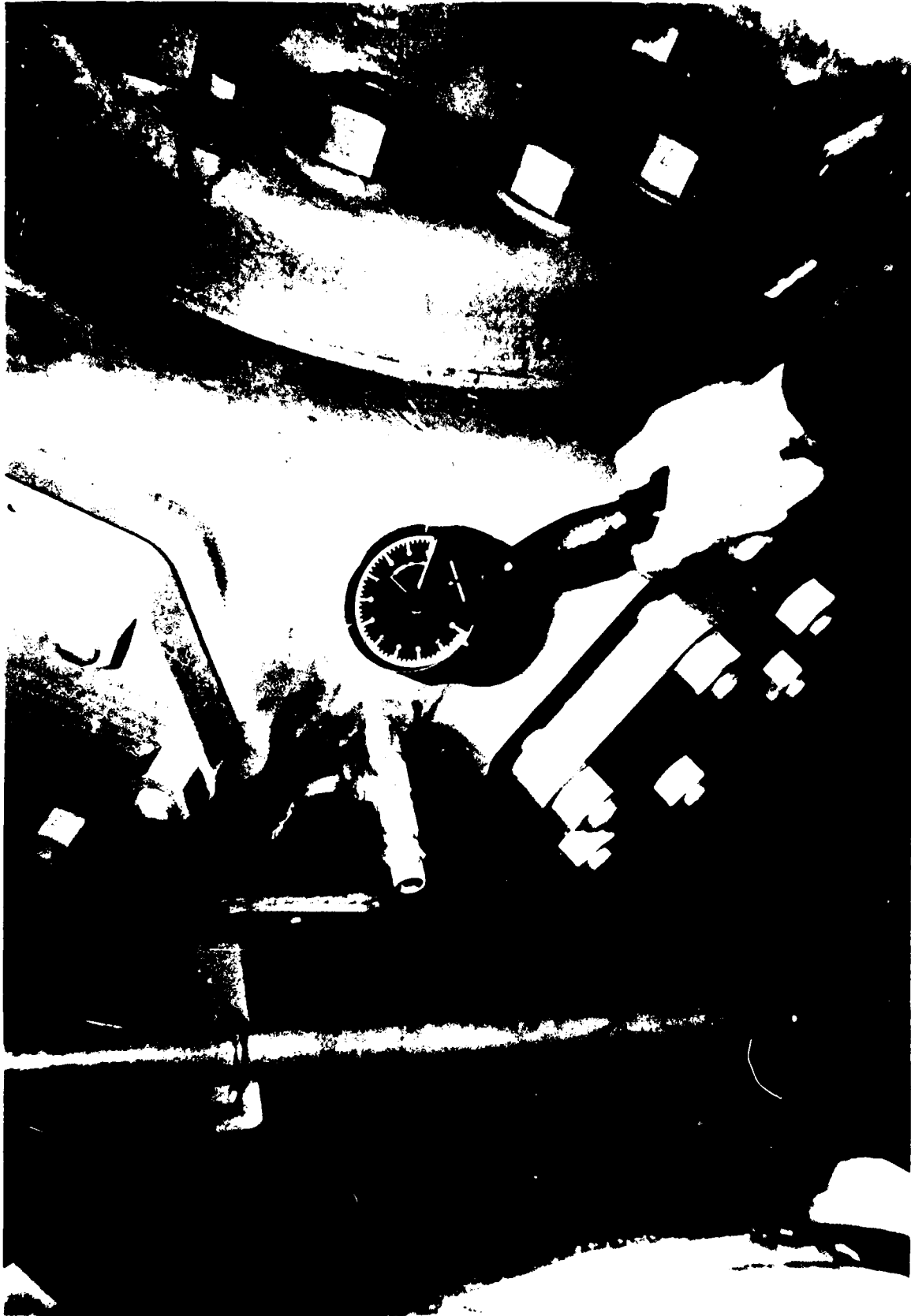


FIGURE L.18. FUEL GAS LEAKAGE FROM DISCHARGE HEAD ON FUEL GAS COMPRESSOR

TABLE L.8

GAS CONCENTRATIONS ON OFFSHORE PLATFORMS

COMPANY:	E
PLATFORM:	D
DATE:	11/11/81

<u>AREA/EQUIPMENT</u>	<u>GAS CONCENTRATION</u> <u>ppm (total as methane)</u>
<u>Well Head Area</u>	
o D-11, 3/4" valve on well head, bubbles of gas appear through oil residue	> 1000 ppm
o D-7, 3/4" valve on well head	> 1000 ppm
<u>Gas Metering Run</u>	
o 3/8" tubing lines from orifice plates on gas lift lines to meter	> 1000 ppm
<u>Demulsifier Injection</u>	
o Bung is open on 55-gal. drum	
- inside barrel	> 1000 ppm
- 1 to 2 feet downwind of bung	30 to 40 ppm
<u>Test Treater</u>	
o Catch pan is evolving vapor from oil on surface	
- at liquid surface	300 ppm
- 8 to 10 feet downwind of pan	20 ppm
<u>Waterflood Pump/Turbine Room</u>	
o Gas fittings on gas turbine	50 ppm
o Fuel gas lines, behind air suction fan	80 to 300 ppm

TABLE L.9
GAS CONCENTRATIONS ON OFFSHORE PLATFORMS

COMPANY: E
PLATFORM: F
DATE: 11/11/81

<u>AREA/EQUIPMENT</u>	<u>GAS CONCENTRATION ppm (total as methane)</u>
<u>Trash Can Compactor</u>	
o Background concentration	50 ppm
o Individual paint cans	1000 ppm
<u>Shale Shaker</u>	
o At operator work locations	5 to 10 ppm
o Above vibrating screen	30 ppm
<u>Shale Shaker (on 11/13, see Figure L.19)</u>	
o Above flowing mud/air interface	40 to 160 ppm
o Above vibrating screen	70 ppm

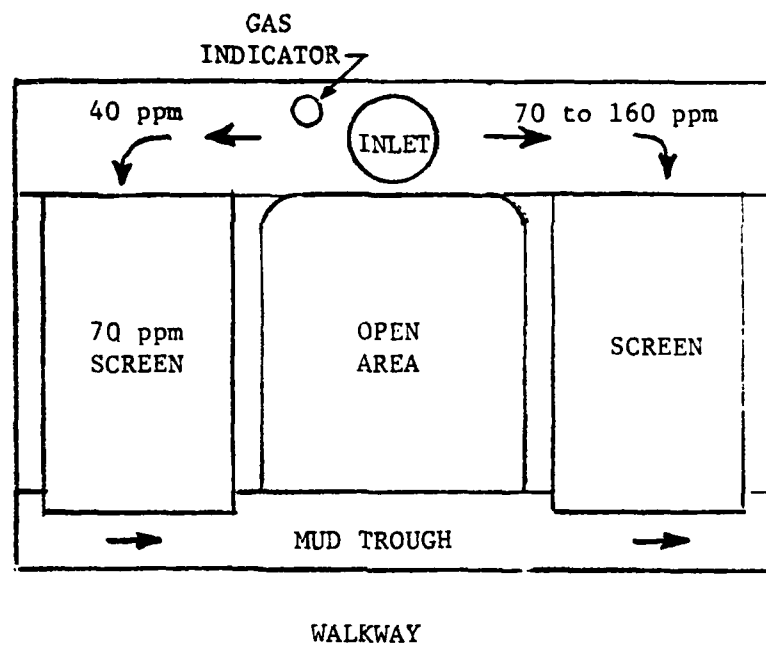


FIGURE L.19 VARIATION OF TOTAL HYDROCARBON CONCENTRATION
NEAR SHALE SHAKER

from the drilling fluid was highest near the inlet and above the screens.

On several occasions the OVA was taken into the living quarters and office spaces on all four platforms. Ambient concentration levels were always low, from 5 to 10 ppm. Both office spaces and living quarters were kept clean, and the general level of "house keeping" in work areas was also very good.

In order to characterize the composition of gases and vapors from the emission sources, samples were collected directly from the emission sources into inert bags for analysis by the OVA in the gas chromatograph (GC) mode. As expected, the GC traces showed the presence of several hydrocarbon gases and vapors. A "Mini-Mix" (Scientific Gas Products, Inc., Sample M1064) calibration gas sample, containing the concentrations of vapors shown in Table IV.2, was analyzed also to identify constituents in the source samples.

Since the concentration of gas contained in the emission source bags was too high to read directly, diluted samples were prepared as 50 ml of gas from the source bag mixed with either 2450 ml of air or 4950 ml of air. This procedure gave samples containing 1 part of emission source gas to either 49 or 99 parts of air. It was relatively simple to identify most of the gas and vapor constituents in the source samples. Figure L.20 compares a GC trace for the "Mini-Mix" calibration gas sample with a trace for a source sample obtained at the flotation cell. Peaks for methane, ethane, propane, iso-(i) and normal-(n) butane, i- and n-pentane, and i- and n-hexane in the calibration gas trace correspond directly to peaks in the source gas trace. The other peaks appearing in the source gas trace have been identified as shown in Figure L.20 by laboratory work at SwRI.

The determination of constituent concentration from the GC traces proved to be more difficult than we had anticipated. It was planned to measure the height of individual peaks, and to determine constituent concentration from a calibration curve of peak height to peak concentration. However, this calibration is strongly affected by GC column temperature. An uncontrolled variation of room temperature of $\pm 2^{\circ}\text{C}$ in the crew living quarters that occurred during GC analysis has made the interpretation of the peak height measurements subject to considerable uncertainty. In these circumstances, an analysis of peak area (area confined beneath the peak and above the baseline) is more appropriate. The results that follow in Tables L.10 through L.14 have been obtained by measurement of peak area and a laboratory calibration of constituent concentration versus peak area. This technique removes the uncertainty caused by temperature variation during analysis.

Table L.10 shows the concentration distribution of methane, ethane and propane determined for a source sample taken at well head C-6 on platform C. No values of butane, pentane or hexane were determined for this sample. Table L.10 shows the concentration values determined from two replicated GC analyses (or trials) and an "average" or best set of values.

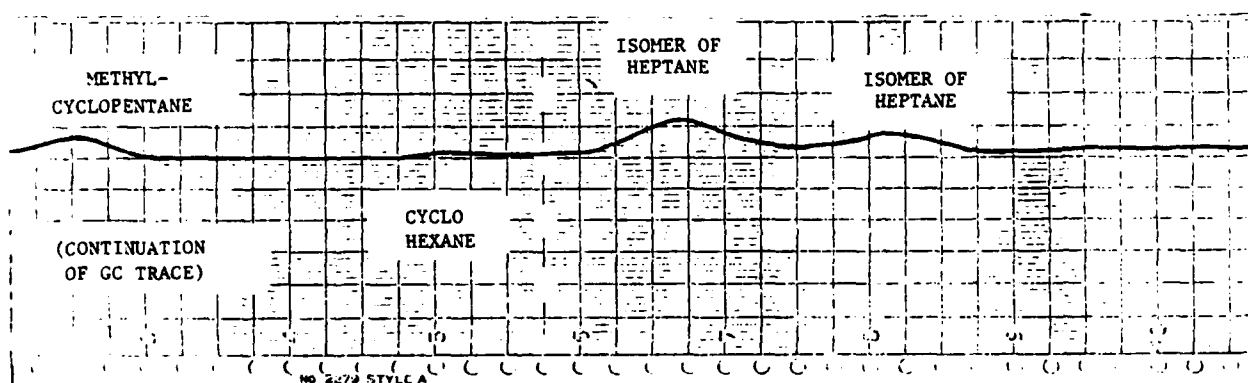
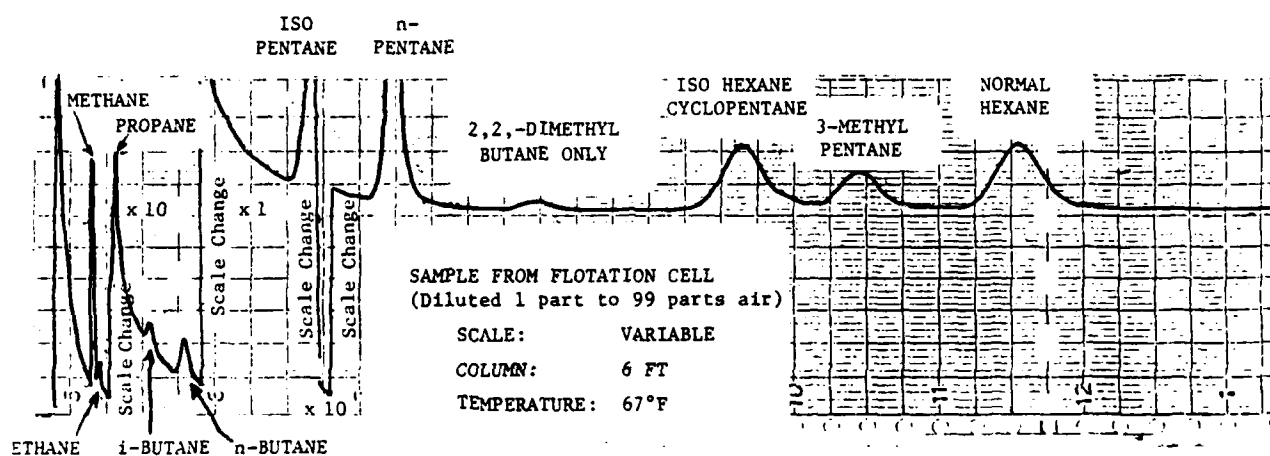
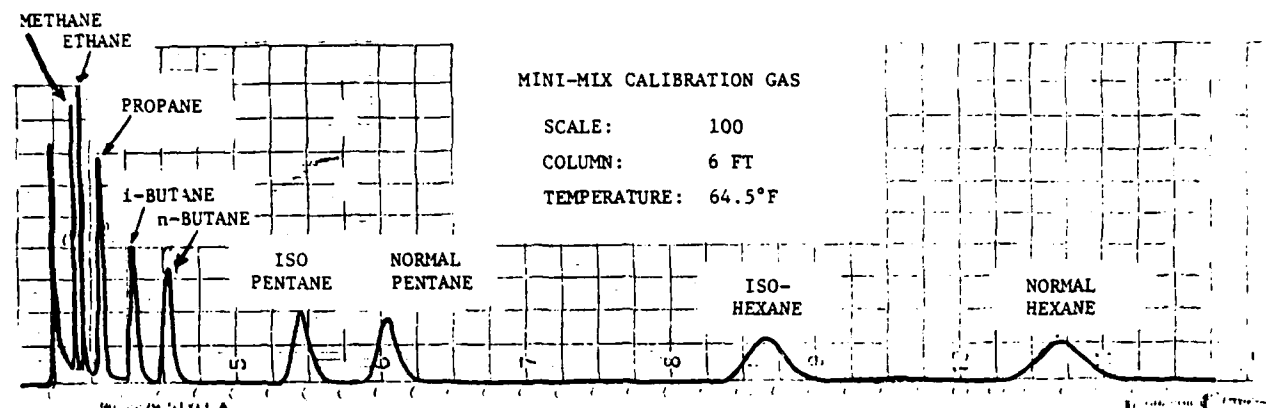


FIGURE L.20 GAS CHROMATOGRAPH TRACES FOR MINI-MIX CALIBRATION GAS AND SAMPLE FROM FLOTATION CELL

TABLE L.10

RESULTS OF SOURCE SAMPLING AT WELL-HEAD - C-6

Sample Number	Dilution Ratio	C ₁ methane ppm	C ₂ ethane ppm	C ₃ propane ppm	1 C ₄ i-butane ppm	C ₄ n-butane ppm	1 C ₅ i-pentane ppm	C ₅ n-pentane ppm	1 C ₆ i-hexane ppm	C ₆ n-hexane ppm
18	1:49	67,800	18,500	15,100 ⁺	*	*	*	*	*	*
18	1:49	38,700	18,500	2,270	*	*	*	*	*	*
Average		53,300	18,500	2,270						

NOTES: * - Peak area too small to resolve accurately.

+ - Peak area is very small, but multiplied by a large scale factor, this value is suppressed.

TABLE L.11

RESULTS OF SOURCE SAMPLING AT WELL-HEAD - C-10

Sample Number	Dilution Ratio	C ₁ methane ppm	C ₂ ethane ppm	C ₃ propane ppm	i C ₄ i-butane ppm	C ₄ n-butane ppm	i C ₅ i-pentane ppm	C ₅ n-pentane ppm	i C ₆ i-hexane ppm	C ₆ n-hexane ppm
17	1:49	*	27,700	15,100	*	*	*	*	*	*
17	1:49	*	37,000	15,100	2,300	3,520	1,060	410	*	*
17	1:99	*	*	*	*	2,460	710	870	230	250
Average			32,400	15,100	2,300	2,990	880	640	230	250

NOTE: * - Peak area too small to resolve accurately.

TABLE L.12

RESULTS OF SOURCE SAMPLING IN COMPRESSOR ROOM

Sample Number	Dilution Ratio	C ₁ methane ppm	C ₂ ethane ppm	C ₃ propane ppm	i C ₄ i-butane ppm	C ₄ n-butane ppm	i C ₅ i-pentane ppm	C ₅ n-pentane ppm	i C ₆ i-hexane ppm	C ₆ n-hexane ppm
18	1:99	77,500	4,800	3,000	1,700	800	530	410	*	*

NOTE: * - Peak area too small to resolve accurately.

TABLE L.13

RESULTS OF SOURCE SAMPLING AT THE FLOTATION CELL

Sample Number	Dilution Ratio	C ₁ methane ppm	C ₂ ethane ppm	C ₃ propane ppm	1 C ₄ 1-butane ppm	C ₄ n-butane ppm	1 C ₅ 1-pentane ppm	C ₅ n-pentane ppm	1 C ₆ 1-hexane ppm	C ₆ n-hexane ppm
16	1:99	108,000	14,800	7,870	3,450	4,220	2,110	4,060	--	--
15	1:49	*	*	*	*	4,100	2,120	1,870	1,010	1,470
16	1:99	*	*	*	*	2,740	1,660	1,870	1,610	1,410
16	1:99	*	*	*	*	*	1,590	1,570	1,450	1,200
Average		108,000	14,800	7,870	3,450	3,690	1,870	1,340	1,360	1,360

NOTE: * - Peak area too small to resolve accurately.

TABLE L.14

RESULTS OF AREA SAMPLING DOWNWIND OF THE FLOTATION CELL

Sample Number	Total Hydrocarbon Concentration ppm	C ₁ methane ppm	C ₂ ethane ppm	C ₃ propane ppm	1 C ₄ 1-butane ppm	C ₄ n-butane ppm	1 C ₅ 1-pentane ppm	C ₅ n-pentane ppm	1 C ₆ 1-hexane ppm	C ₆ n-hexane ppm
14	> 1000 Offscale	* (1200)	* (160)	* (87)	* (38)	15.5 (41)	26.7 (21)	21.6 (26)	16.0 --	14.1 --
15	650	* (220)	* (30)	* (16)	* (7.1)	5.6 (7.6)	4.7 (3.9)	3.4 (4.8)	2.9 --	2.7 --
19	320	* (170)	* (23)	* (12)	* (5)	2.6 (5.8)	2.3 (2.9)	2.9 (3.7)	2.3 --	2.0 --

NOTES: Values in parentheses are estimated from the ratio of hexane to C₁ through C₅ in the Source Sample, Table L.13.

* - Peak area was too small to resolve accurately.

Although the identical value of 18,500 ppm was determined for ethane concentration, there is considerable variability in both the measurement of methane concentration and propane concentration.

The concentration of methane in source samples has been difficult to estimate from a measurement of peak area. As shown in Figure L.20, the methane peak is very tall and also very narrow. Hence, the two different values, 67,800 ppm and 38,700 ppm, of methane concentration given in Table L.10 are due to the uncertainty in measuring peak area (this was performed graphically with a planimeter) for the very narrow methane peak. In future tests, we will reduce this uncertainty by using a strip chart recorder with a faster chart speed to give more width to the methane peak. However, for this sample, our best estimated value of methane concentration must be the arithmetic average, 53,300 ppm, of the two trial values given above.

We also had some difficulty in estimating the propane concentration values shown in Table L.10. The first trial gave a value of 15,100 ppm for the propane concentration. However, this estimate is the product of a very small peak area and a large scale factor. For the second trial, the concentration range on the GC was reduced from X100 to X10 with the result that the propane peak was larger and easier to integrate. Therefore, we believe that the propane concentration value of 2270 ppm determined for the second trial is the more accurate of the two values.

Table L.11 shows the concentration distribution of ethane through hexane for a source sample taken at well head C-10 on platform C. No values of methane concentration were estimated for this sample because the methane peak was off-scale for each replicate trial as explained below. Table L.11 shows the concentration values determined from three replicated GC trials. Fair agreement is found between replicated values of concentration for ethane, propane, n-butane, i-pentane, and n-pentane. The first trial in Table L.11 was performed with a dilution ratio of 1 part sample to 49 parts air and a concentration range of X100. The methane peak was off-scale for this trial, but good resolution was obtained for the ethane and propane peaks. The column was back-flushed before the butane peaks eluted. Therefore, no estimates of concentration for butane through hexane were obtained from this first trial.

The second trial in Table L.11 was performed with a dilution ratio of 1 part sample to 99 parts air. A concentration range of X100 was used for the methane, ethane and propane peaks. However, the methane peak was still off-scale. The concentration range of X10 was used for the butane and pentane peaks. The third replicate trial used only the X10 and X1 concentration ranges in an effort to extend the analysis out to include hexane. Table L.11 shows fair agreement between the estimated values of concentration for n-butane, i-pentane and n-pentane for the second and third trials. The set of average or best estimate values of hydrocarbon concentration in Table L.11 shows the trend of decreasing concentration for increasing hydrocarbon number that is expected for emissions from crude oil.

Table L.12 shows the concentration of methane through pentane for a source sample taken in the fuel gas compressor room on platform C. One trial was performed with a dilution ratio of 1 part sample to 99 parts air. A concentration range of X100 was used for the methane peak, X10 for the ethane, propane and i-butane peaks, and X1 for n-butane and the pentane peaks. Resolution of each peak was fairly good. However, the peak area for iso-butane was only 50% greater than the minimum resolvable area (0.01 in² by planimeter), and the uncertainty in the reported concentration value of 1700 ppm is higher than for the other values. If we take the values of fuel gas concentration shown in Table L.12 and express them as concentrations in mole percent, we obtain the following concentration distribution for fuel gas on platform C.

o	Methane	87.3%
o	Ethane	5.4%
o	Propane	3.4%
o	I-Butane	1.9%
o	N-Butane	0.9%
o	I-Pentane	0.6%
o	N-Pentane	0.5%

Dry natural gas, with condensibles removed, usually has a methane concentration in the range of 85 to 95%.

Table L.13 shows the concentration distribution of methane through hexane for a source sample taken at the flotation cell on platform C. Four replicated samples were analyzed for dilution ratios of 1 to 99 and 1 to 49. Again, fair agreement is found between replicated values of concentration for n-butane, i- and n-pentane, and i- and n-hexane. Concentration values of methane, ethane, propane, and iso-butane were determined from a single trial. However, the concentration ranges used during the analysis gave fairly good resolution of these peaks, particularly the ethane peak. The flotation cell source concentration distribution may be expressed as mole percent concentration as follows:

o	Methane	74.6%
o	Ethane	10.2%
o	Propane	5.4%
o	I-Butane	2.4%
o	N-Butane	2.5%
o	I-Pentane	1.3%
o	N-Pentane	1.6%
o	I-Hexane	0.9%
o	N-Hexane	0.9%

Fuel gas was bubbled up through the flotation cell to lift small suspended oil droplets to the surface for skimming. However, the percentage of methane in the flotation cell source sample is lower than expected for fuel gas alone. The increased amounts of ethane, propane, butane, and pentane in the flotation cell sample may be the result of vapor evolved from the wet oil which collects on the surface before being skimmed away.

Area sampling for gas and vapor contaminant concentration was performed at two locations, downwind of the flotation cell and in the fuel gas compressor room on platform C. During the initial walk-through survey we noticed that the odor of gas from the flotation cell was quite noticeable around the drilling fluid cleaning equipment on the workover rig. That equipment is located only about 2 to 3 meters from the flotation cell. Therefore, it was likely that a roughneck standing above the brine pit would be exposed to the gas and vapor cloud from the flotation cell.

Three area sampling receptors were arranged downwind of the flotation cell as shown in Figure L.21. Station 15 was located in front of the blowout preventer control console. Station 16 was located next to the flotation cell on a walkway. Station 19 was located on a ladder landing by the brine pit for the workover rig. Samples of air were drawn at a height of 1.67m through MSA C-200 sampling pumps into inert bags, for a period of 10 minutes as shown in Figure L.22. These samples were then analyzed for their total hydrocarbon concentration, and for the distribution of hydrocarbon gas concentration by GC.

Table L.14 shows the results of the area sampling test downwind of the flotation cell. Station 14, nearest to the flotation cell, had the highest value of total hydrocarbon concentration, followed by Stations 15 and 19. The wind was blowing along a direction nearly parallel to the flotation cell, so that the lower value of concentration at the workover rig is not surprising.

Each of the three area sample bags was analyzed directly by gas chromatograph. Two values of concentration are shown for each sample. The upper value is the one determined from the GC analysis. The lower value is estimated from the ratio of constituent concentrations determined for the flotation cell source sample in Table L.13. In general, the estimated and measured values are in fairly good agreement. It is interesting to note that the estimated and measured values of concentration for the butanes, pentanes, and hexanes are all below 50 ppm at all 3 work stations.

Methane, ethane and propane gases are classed as simple asphyxiants. These gases are safe to breathe so long as they do not displace too much air and oxygen from the breathing zone. Air normally contains about 21% oxygen by volume. For work to be performed normally, the oxygen concentration in the breathing zone should not be lower than 16.5%. A concentration of methane, ethane and propane of 21.5% will reduce the oxygen level to

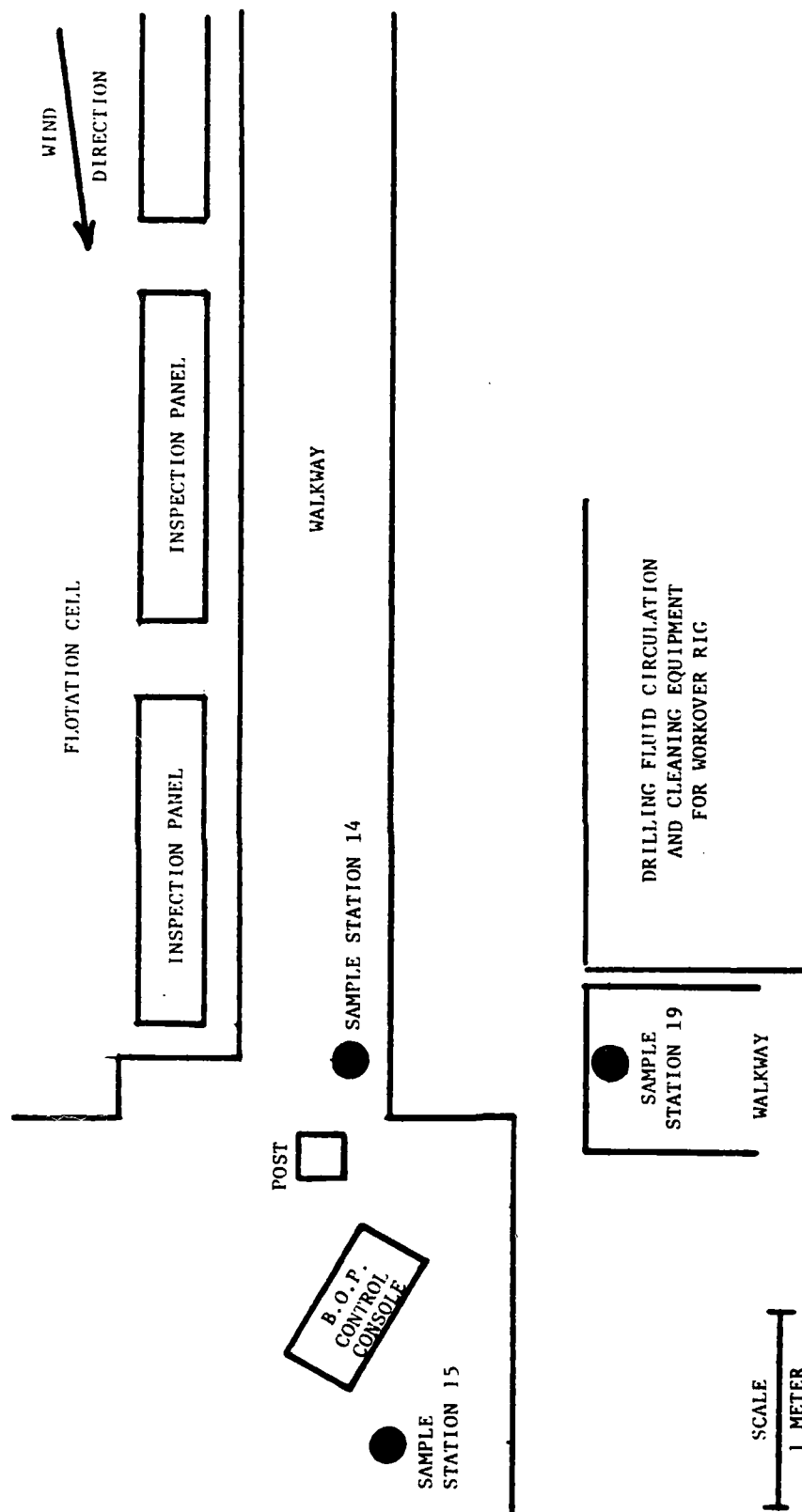


FIGURE L.21 ARRANGEMENT OF AREA SAMPLING STATIONS
DOWNWIND OF FLOTATION CELL

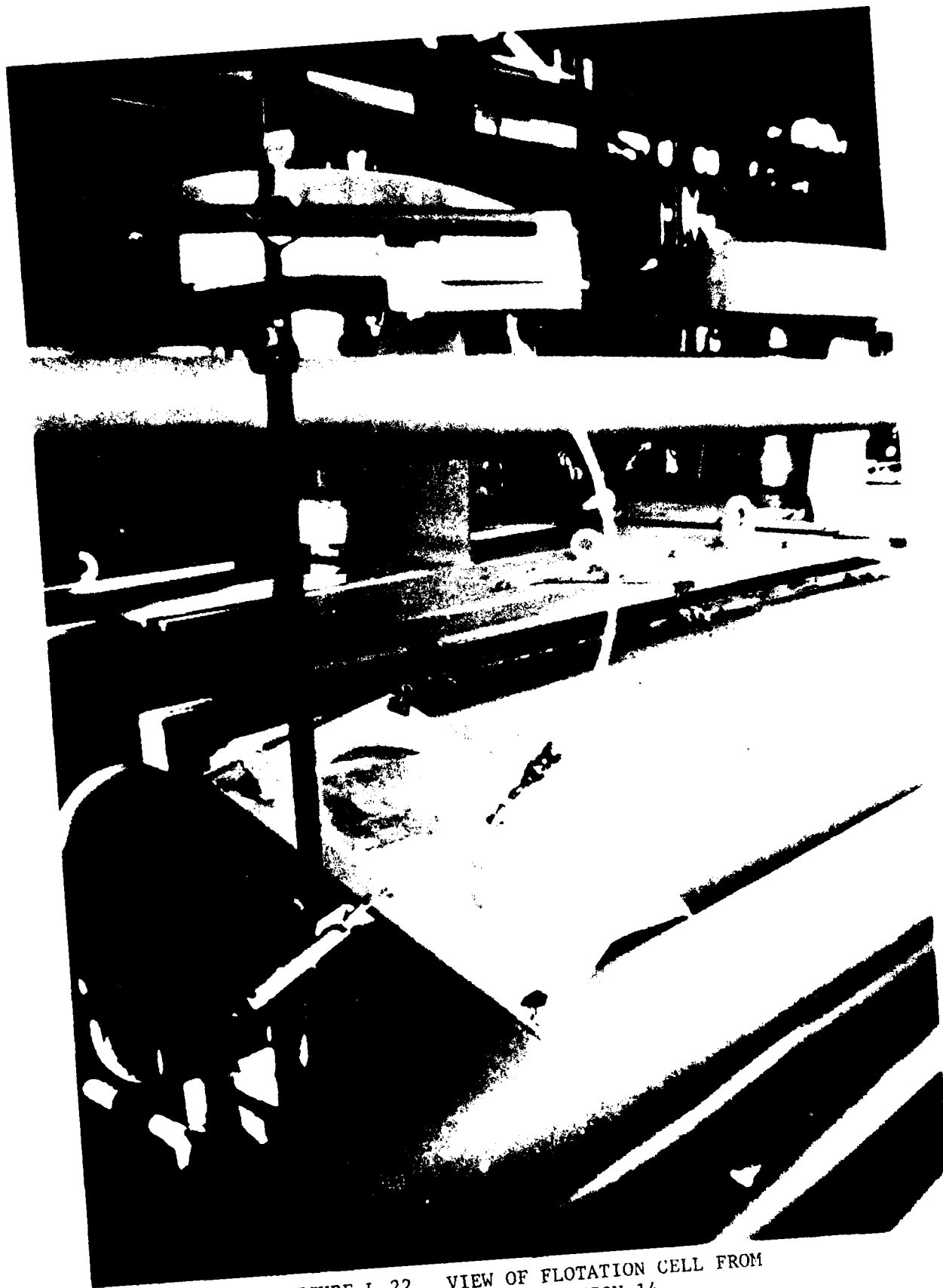


FIGURE L.22. VIEW OF FLOTATION CELL FROM
AREA SAMPLING STATION 14

$$0.785 \times 21\% = 16.5\%$$

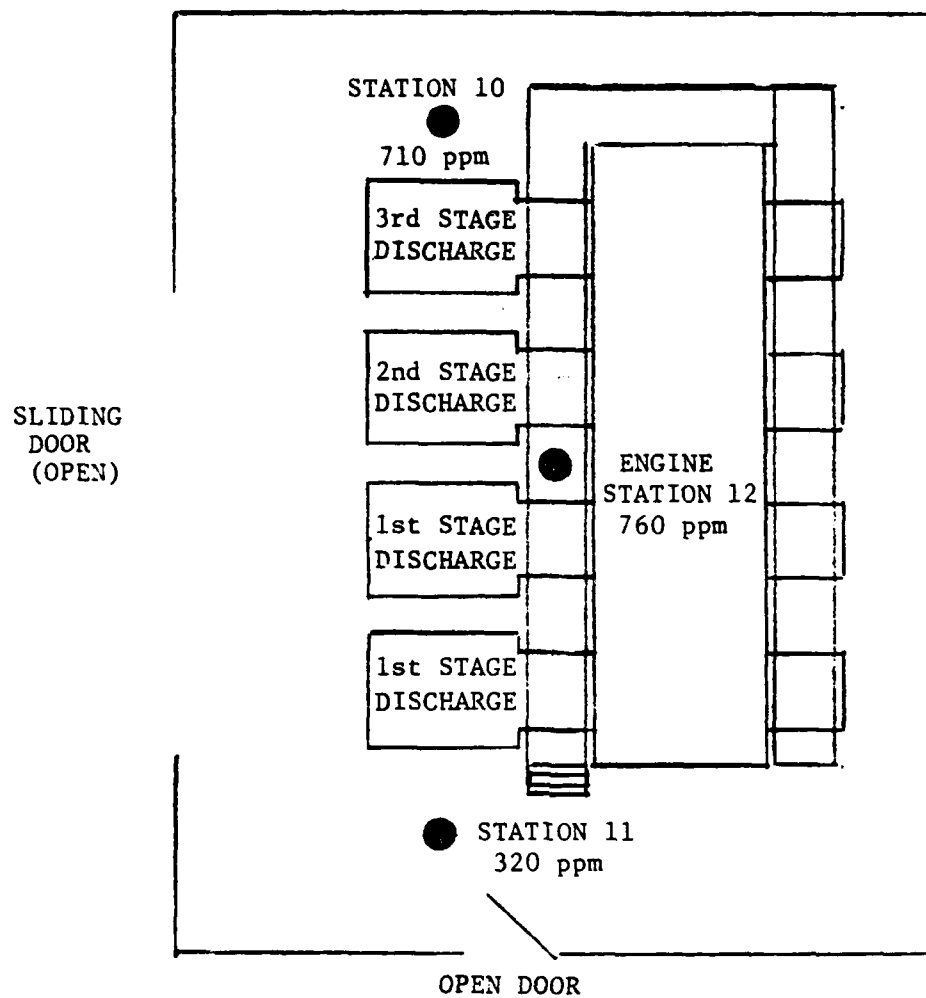
and still produce a breatheable atmosphere. It would be unusual, however, to find accumulations of methane, ethane, and propane at concentrations within the flammable range on offshore platforms. Enclosed workplaces such as fuel gas compressor rooms, engine generator rooms, fuel gas turbine rooms, and instrument maintenance sheds are protected by a combustible gas detection system. The detector system will sound an audible alarm at 20% of the LEL and shut-in the platform when the gas concentration reaches 60% of the LEL. Alarm levels are set in the field with calibration mixtures of methane (LEL = 5%) and air.

The maximum acceptable workplace concentrations for butane, pentane, and hexane are given by the TWA-TLV (time weighted average-threshold limit value). Values given in Appendix J for the TWA-TLV are

o Butane (n-butane)	800 ppm
o Pentane (n-pentane)	600 ppm
o Hexane (n-hexane)	50 ppm
(other isomers)	500 ppm

Inspection of the results given in Table L.14 for area sampling downwind of the flotation cell shows that the concentrations of these gases were all below the maximum permissible TWA-TLV level.

Area sampling was also performed in the fuel gas compressor room. The location of the area sampling stations and the total hydrocarbon concentration values are shown in Figure L.23. Gas chromatograph analysis of these samples showed that they contained a large percentage of methane, ethane, and propane. A hexane concentration could not be detected in the compressor room (in contrast to the flotation cell where hexane is easily detected). The concentration distribution determined for the area samples in the compressor room is below the maximum permissible TWA-TLV level by current standards.



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(TO SCALE)

FIGURE L.23. AREA SAMPLING STATIONS IN THE FUEL GAS COMPRESSOR ROOM ON PLATFORM C

APPENDIX M

ABSTRACTS ON ARTICLES COVERED
DURING SURVEY OF NOISE LITERATURE

618105 ID NO. - E1760318105
NOISE ON OFFSHORE PLATFORMS.

Melling, T. H.

Acoust Technol Ltd

Noise Control Vib Reduct v 6 n 7 Jul 1975 p 205-209

CODEN: NCVRBA

Designers of the new generation of offshore platforms are increasingly aware of the need to design for noise control right back on the drawing board. Retrospective noise control has proved to be a cause of lengthy delays and expensive troubleshooting exercises. This new generation of structures has still to enter service, so operational measurements of noise have not yet been possible. However, comprehensive measurements have been made on existing drilling/exploration rigs, and show clearly the problems which can occur when noise control is not considered at design stage. Measurements on a typical rig of this type showed that the areas of greatest noise are the drilling platform, the engine room, the mud and cement pump areas, and the accommodation area. These data are shown in a table. The following maximum permissible noise levels are proposed for the basic areas aboard offshore platforms: 1. Work areas: Maximum noise level 90dBA (NR 80 to NR 85) for an 8-hour shift, and pro-rata on an energy basis for any other shift length, (eg 88dBA for a 12-hour shift). 2. Control rooms: Maximum noise level 60dBA (NR 50 to NR 55) for effective speech communication. 3. Accommodation areas: Maximum noise level 45dBA (NR 35 to NR 40) for effective sleep. The general theoretical concepts relating to noise generation and abatement are considered.

DESCRIPTORS: (*MARINE PLATFORMS, *Noise Abatement), (NATURAL GAS WELLS, Offshore),

CARD ALERT: 512, 674, 751

568117 ID NO. - E1751068117
MEASUREMENTS OF THE NOISE AND VIBRATION ENVIRONMENTS IN AN OPERATIONAL NORTH SEA PLATFORM AND COMPARISON WITH DESIGN LEVELS.

Melling, T. H.; Postlethwaite, B. C.; Davies, R. J.

Acoust Technol Ltd

Offshore Technol Conf, 7th Annu, Proc, Pap, Houston, Tex, May 5-8 1975 v 1, Pap OTC 2236, p 871-880. Publ by Offshore Technol Conf, Dallas, Tex, 1975

The paper describes noise measurements carried out on North Sea drilling and production platforms. The work provides interesting comparison between desirable and typical noise levels when noise has not been considered as a design input. The dynamic behavior of a compressor skid/cellar deck is discussed highlighting the potential pitfalls of neglecting such analyses at the design stage. 2 refs.

DESCRIPTORS: (*OIL FIELD EQUIPMENT, *Noise, Acoustic), (COMPRESSORS, Vibrations),

CARD ALERT: 511, 618

539670 ID NO. - E1750639670

GIGIENICHESKAYA KHARAKTERISTIKA SHUMA NA BUROVYKH. \$left
brackets\$ Hygienic Characterization of Noise on Drilling Rigs
\$right brackets\$.

Reznik, V. L.

Neft Khoz n 1 Jan 1975 p 45-48 CODEN: NEKIIA6

The results of studies of the noise factor on four drilling rigs are presented. The dependence of the noise intensity of the technological process being carried out and the choice of the point of measurement on the type of drilling rig is determined. A comparative hygienic evaluation of these rigs with respect to the noise factor is made, and measures designed to reduce noise and to prevent it from adversely affecting the health of workers of the drilling crew are indicated. In Russian.

DESCRIPTORS: (*OIL WELL DRILLING, *Noise Abatement), NOISE ABATEMENT, INDUSTRIAL HYGIENE.

CARD ALERT: 511, 751, 914

471974 ID NO. - E1741171974

NOISE CONTROL ENGINEERING EXPERIENCE WITH OFFSHORE OIL AND GAS PLATFORMS AND RELATED REFINERY AND PROCESS EQUIPMENT.

Pelton, H. K.

Joiner-Pelton-Rose, Inc. Dallas, Tex

ASME Pap n 74-Pet-43 for Meet Sep 15-18 1974, 8 p CODEN:

ASMSA4

Noise is now being recognized as a design parameter in all of industry. However, there are installations of mechanical and process equipment requiring noise control engineering evaluation to meet the current operational noise exposure standards. Offshore oil and gas platforms present some unique and challenging problems for the noise control engineer, in view of the relatively lightweight and rigid steel construction. This paper will define some of the problems, discuss the magnitude of the noise levels, the costs of noise control, and provide some solutions to various types of noise sources.

DESCRIPTORS: (*OIL WELL PRODUCTION, *Offshore), (MARINE PLATFORMS, Noise Abatement), (OIL FIELD EQUIPMENT, Vibrations)

CARD ALERT: 511, 674

780563 ID NO. - E1771180563

OFFSHORE DRILLING AND PRODUCTION NOISE LEVELS AND ACOUSTIC COMMUNICATIONS RELIABILITY-FIELD DATA.

Heckman, Donald B.

AMF Sea-Link Syst

Offshore Technol Conf 9th Annu, Proc, Houston, Tex, May 2-5 1977. Sponsored by AIME, New York, NY, 1977 v 2 Pap OTC 2877 p 553-556 CODEN: OSTCBA

This paper describes acoustic noise surveys and communication reliability tests conducted on and near offshore drilling and production platforms in the Gulf of Mexico in September 1975. The objective of these tests was to measure noise spectrum levels of typical drilling and production operations and to evaluate the new AMF Sea-Link Digital Acoustic Command System (DACS) in such an environment. Test results of a long-term deployment of a DACS underwater unit adjacent to a subsea production has been designed to meet the

stringent requirements needed for application in the offshore environment for such applications as acoustic buoy release, valve control, subsea production control, blowout preventor control, etc. The coding techniques employed in the DACS equipment are briefly described. The noise data are presented and compared with other published data. The characteristics of the noise as they affect the performance of various acoustic coding techniques are discussed. 2 refs.

DESCRIPTORS: (*DRILL SHIPS, *Remote Control), (NOISE, ACOUSTIC, Spectrum Analysis), ACOUSTIC EQUIPMENT.

IDENTIFIERS: ACOUSTIC COMMAND SYSTEMS

CARD ALERT: 671, 751, 752

775046 ID NO.- E1771075046

NOISE EXPOSURE AND CONTROL ON FIXED MARINE STRUCTURES.

Judd, Stanley H.

Stand Oil Co of Calif, San Francisco

SV Sound Vib v 11 n 5 May 1977 p 20-24 CODEN: SOVIAJ

Machinery noise sources on drilling and producing platforms include engines, turbines, gears, generators, pumps and compressors. Noise transmission is both structureborne and airborne. Exposure evaluation requires consideration of work shifts ranging up to 12 hours per day, seven days in a row. Exposure time is not limited to the work shift for those who must live on the structure. The design problem is to avoid or eliminate excessive noise levels. If this is not feasible, noise levels are minimized both as to intensity and the physical area affected by use of quite machinery. Enclosure and/or other acoustical treatment is then used to bring exposure within acceptable limits. Examples of noise sources and control measures are illustrated by case histories.

DESCRIPTORS: (*MARINE PLATFORMS, *Noise Abatement),

CARD ALERT: 674, 751

471191 ID NO.- E1741171191

DESIGNING TO MEET SPECIFIC NOISE AND VIBRATION CRITERIA ON OFFSHORE PLATFORMS.

Melling, T. H.; Davies, R. J.

Acoust Technol Ltd

Offshore Technol Conf, 6th, Annu, Prepr, Pap, Houston, Tex, May 6-8 1974 v 2, Pap 2054, p 237-247. Publ by Offshore Technol Conf, c/o David L. Riley, Dallas, Tex

Noise control in the offshore industry introduces novel problems to the oil industry. The major differences between offshore and onshore noise control are discussed, and the concepts of noise control in terms of direct sound from the equipment, the reverberant noise introduced when the equipment is enclosed in a module, and problems of structure-borne noise are developed and illustrated with examples. 4 refs.

DESCRIPTORS: (*MARINE PLATFORMS, *Vibrations), (OIL WELL PRODUCTION, Noise Abatement), NOISE, ACOUSTIC.

CARD ALERT: 511, 674, 751

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